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Rev. 07/10/02

FINAL

Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site

Baseline Ecological Risk Assessment

Prepared for:

**Michigan Department of Environmental Quality
Environmental Response Division**

DEQ

by:

Camp Dresser & McKee
One Woodward Avenue, Suite 1500
Detroit, Michigan 48226

June 1999

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EXECUTIVE SUMMARY

This Executive Summary presents an overview of the Ecological Risk Assessment (ERA) for the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site (API/PC/KR) in Southwestern Michigan. The primary purpose of this ERA is to identify and describe actual or potential onsite conditions that can result in unacceptable risks to exposed organisms. Sufficient recent site-specific information indicates that this ERA should focus on the primary chemical stressors present at this site--polychlorinated biphenyls (PCBs). This ERA compares measured or estimated PCB concentrations in different types of exposure media (e.g., surface water, sediment, fish) with predicted biological effects to estimate risks and to preliminarily identify appropriate and protective cleanup levels.

BACKGROUND AND SITE DESCRIPTON

Due to the PCB contamination, in August 1990 the site was placed on the Superfund or National Priorities List (NPL). The NPL Study Area (API/KR/PC) defined in the Michigan Environmental Response Act 307 includes three miles of Portage Creek, from Cork Street to its confluence with the Kalamazoo River, and 80 miles of the Kalamazoo River, from Morrow Lake Dam downstream to Lake Michigan. Also included in the site are five paper residual disposal areas and five paper mill properties.

The Michigan Department of Community Health has issued a species-specific no consumption fish advisory annually since 1977 for the Kalamazoo River portion of this site due to PCB contamination. The Kalamazoo River and Portage Creek also have been designated a site of environmental contamination under Part 201, Environmental Remediation, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA), due to PCB contamination. The Kalamazoo River and Portage Creek have been identified as an Area of Concern by the International Joint Commission on the Great Lakes due to the detrimental impact the release of PCBs have on Lake Michigan.

GENERAL APPROACH TO ERA

This ERA follows EPA guidance for conducting ERAs, primarily Ecological Risk Assessment Guidance for Superfund (EPA 1997) and Guidelines for Ecological Risk Assessment (EPA 1998). The major components of the ERA include Problem Formulation, Analysis, and Risk Characterization. The Problem Formulation phase of this ERA establishes the goals and describes the scope and focus of the assessment. In addition, this phase considers site-specific regulatory and policy issues and requirements and preliminarily identifies potential stressors and ecological resources potentially at risk. The outcome of Problem Formulation is the site-specific conceptual model, which describes potential exposure pathways and the relationship between remedial action objectives, assessment endpoints and measurement endpoints. Uncertainties associated with this phase of the ERA are included at the end of this section.

The Analysis phase of the ERA describes the nature and extent of contamination (Exposure Assessment) and identifies appropriate and relevant threshold concentrations, standards, or criteria for contaminants of concern (Effects Assessment). Uncertainty analysis related to this phase of the ERA is also included.

The final major component of the ERA, Risk Characterization, considers the information gathered in Problem Formulation and integrates Exposure and Effects data to estimate risks to ecological receptors. Also included in Risk Characterization is a discussion of ecological significance, risk summary, and uncertainty analysis.

This ERA also includes an additional section on Remediation Issues in which preliminary risk-based remediation or clean up goals are developed.

This ERA uses several lines of evidence to increase confidence in risk estimates and ERA conclusions. These include the use of simple hazard quotients that compare a single selected exposure concentration to a single selected effects concentration to derive a quotient. This is a common screening level approach for identifying issues of most concern. Supplementing this approach is a comparison of multiple media-specific exposure concentrations for specific site locations to multiple effects concentrations that include site-specific and literature-based values. This approach reduces the uncertainties in relying on single exposure and effects concentrations and contributes to the weight-of-evidence. Also included in this ERA is a food chain model that estimates PCB dose via ingestion pathways for key receptor species or groups. Finally, this ERA considers field observations and other qualitative data as a check on risk estimates and conclusions.

REPRESENTATIVE RECEPTORS

Potential ecological receptors for this study are defined as plants and animals that inhabit or use, or have potential to inhabit or use, the aquatic, riparian/wetland and terrestrial habitats of the API/PC/KR. The large number of potential receptor species identified for the API/PC/KR obviously precludes an assessment of potential risks for every species listed. Several species or groups of organisms have therefore been selected to serve as representative receptors for a detailed evaluation of potential risks. These include aquatic plants, aquatic macroinvertebrates, game fish (e.g., smallmouth bass), forage fish (e.g., sucker), rough fish (e.g., carp), terrestrial invertebrates (e.g., earthworms), small burrowing omnivorous mammals (e.g., deer mouse), semi-aquatic herbivorous mammals (e.g., muskrat), small semi-aquatic carnivorous mammals (e.g., mink), and top mammalian and avian predators (e.g., red fox, great horned owl, bald eagle).

ERA-RELATED GOALS AND OBJECTIVES

ERA-related remedial action goals and objectives for the API/PC/KR have been determined by MDEQ, and include: (1) the establishment and maintenance of a healthy and diverse aquatic and riparian cosystems in and adjacent to the API/PC/KR, and (2) reductions in PCB concentrations in fish and wildlife such that human consumption restrictions can be lifted.

SITE CONCEPTUAL MODEL

The site conceptual model (SCM) is the primary output of the Problem Formulation phase of the ERA, and is used to develop a series of null hypotheses for the API/PC/KR, primarily those regarding potential exposure scenarios and the relationship between selected assessment and measurement endpoints. The null hypotheses for the API/PC/KR are defined as follows:

1. The levels of contaminants in water, sediment, and biota are not sufficient to adversely affect the structure or function of the fish populations in the Kalamazoo River and Portage Creek System.

2. The levels of contaminants in water, sediment, and biota are not sufficient to adversely affect the survival, growth, and reproduction of plant and animal aquatic receptors utilizing the Kalamazoo River and Portage Creek system.

3. The levels of contaminants in water, sediment, soil, and biota are not sufficient to adversely affect the survival, growth, and reproduction of mammalian receptors utilizing the Kalamazoo River and Portage Creek system.

4. The levels of contaminants in water, sediment, and biota are not sufficient to adversely affect the survival, growth, and reproduction of of avian receptors utilizing the Kalamazoo River and Portage Creek system.

SUMMARY OF CONCLUSIONS

Hazard Quotient-based Risks

Hazard quotients based on direct toxicity for aquatic biota and dietary dose for other species reveal that mink are at most risk compared to other representative receptors. This preliminary conclusion is supported by multiple lines of evidence described in the ERA.

Overall Risk Summary

Multiple lines of evidence are used to reach the following conclusions.

- Most aquatic biota such as invertebrates and fish are unlikely to be adversely affected by direct contact with and ingestion of surface water because of relatively low PCB toxicity to most aquatic biota. Bioaccumulation of PCBs is not considered at this stage.

- PCB contamination of surface water and streambed sediment is likely to indirectly but potentially greatly affect sensitive piscivorous predators, such as mink, through consumption of PCB-contaminated prey, especially fish.

  — Impaired reproduction of mink and ultimately decreases in mink populations are the most likely effects of PCB contamination in aquatic prey. There is evidence that mink populations are declining or are reduced.

  — Other piscivorous predators, such as bald eagles, may be at risk if fish are the predominant prey item consumed and if foraging takes place mostly within contaminated aquatic areas. Field investigations of bald eagles by U.S. Fish and Wildlife suggest there has been a loss of reproductive capacity and decrease in the populations of bald eagles within the site boundaries..

- Terrestrial and semi-aquatic biota may be at risk from PCB-contaminated floodplain sediment and surface soil, depending on life history (e.g., foraging behavior, diet, mobility) and sensitivity to PCBs. Such risk are in general considered to be low to moderate, depending on species.

  — Carnivorous terrestrial species (represented by the red fox) are unlikely to be at significant risk unless foraging is concentrated in riparian areas with contaminated floodplain sediment and diet consists of prey that (1) reside in PCB-contaminated areas, and (2) have taken up substantial amounts of PCBs.

  — Omnivorous terrestrial species (represented by mice) are also unlikely to be at significant risk unless they reside in the most contaminated areas. PCB uptake in mice appears to be relatively low.

  — Omnivorous birds (represented by the robin) that consume a substantial amount of vegetation, would be at significant risk only if PCB uptake in plants approached the predicted uptake rate used in the ERA. The predicted uptake rate for terrestrial plants in dry environments is believed to be over-estimated to some extent. Consumption of terrestrial invertebrates such as earthworms is expected to contribute more to total PCB intake than ingestion of plants. Diets high in contaminated invertebrates would increase risks for omnivorous birds.

— Semi-aquatic herbivorous mammals (represented by muskrat) may be at risk from PCB contamination because estimated dietary doses exceed recommended threshold values for rats. This conclusion is based on the assumption that laboratory rats and muskrats are equally sensitive to PCBs via ingestion. Muskrats contaminated with PCBs may also cause adverse effects to muskrat predators because some muskrats contain PCBs in excess of recommended dietary limits for PCB-sensitive predators such as mink.

This ERA presents overwhelming evidence that, despite uncertainties identified in the ERA, two and possibly three of the four proposed null hypotheses can be rejected with little reservation. The first hypothesis is accepted because there is no direct evidence that fish communities are being affected by PCB contamination. The impaired fish community of Lake Allegan is comprised primarily of stunted and often malformed carp. The cause of these findings cannot be determined from the available data. It is noted, however, that PCBs cause a wasting syndrome in several mammalian species. There is insufficient site-specific data to determine if fish communties in the Kalamazoo River are being affected by PCB contamination. The second hypothesis is conditionally accepted/rejected. This is based on the finding that at some locations the maximum detected surface water PCB concentration exceed or closely approach the lowest chronic value for freshwater fish or aquatic plants. The last two hypotheses are rejected because risks to mammalian (e.g. mink) and avian predators (e.g. bald eagle), especially those that consume fish, are unacceptable. These conclusions are based primarily on the very high levels of PCB concentrations in fish and other biota, and abiotic (e.g. floodplain sediments) media.

The ecosystem associated with the API/PC/KR portion of the Kalamazoo River has been and is currently being adversely affected by PCBs originating from past industrial activities. This evidence by the distribution of PCBs in biota at all trophic levels within the API/PC/KR.

REMEDIATION ISSUES

The selection of the most appropriate methods for achieving remediation goals is not a risk assessment issue but is a risk management issue to be addressed in the feasibility study (FS) for this API/PC/KR. The application of cleanup values is also considered a risk management decision. This risk assessment derives and recommends single point threshold PCB concentrations ("cleanup values") for each media type. These single point values are not necessarily intended to be applied to all locations within the API/PC/KR or within a sub-area of the API/PC/KR. For example, it is probably most appropriate to use a single point cleanup value as an average media-specific post-remediation concentration goal within a specific area.

Alternatively, a single point cleanup value can be considered a "never to exceed" value for any onsite sample, but such an application might result in needlessly exceeding remediation goals and costs in most areas within the site. It is most appropriate for risk managers rather than risk assessors to decide how to best apply cleanup values recommended in the risk assessment.

The proposed cleanup levels for various media for the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site are presented below.

- **Surface water total PCB concentrations should not exceed 0.00038 ug/L** to protect mink, the most sensitive of all animals tested to date.

- **Streambed sediment total PCB concentrations should not exceed 0.12 mg/kg** to protect mink, the most sensitive of all animals tested to date.

- **Surface soil and in some cases floodplain sediment PCB concentrations should not exceed 0.7 mg/kg** to protect omnivorous songbirds such as robins, the most sensitive omnivorous terrestrial species evaluated in this ERA.

Section 1
Introduction

This document presents the baseline ecological risk assessment (ERA) for the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site (API/PC/KR) in Southwestern Michigan. This assessment uses site-related chemical concentrations, exposure potential, and toxicity information to characterize potential risks to ecological receptors from releases of polychlorinated biphenyls (PCBs) to the Kalamazoo River ecosystem. Risks are estimated assuming no remedial action has occurred at the site, and are intended to assist the risk manager in determining the acceptable clean-up levels to protect ecological receptors.

1.1 Report Objectives

ERAs evaluate the likelihood that adverse ecological effects may occur or are occurring at a site as a result of exposure to single or multiple chemical or physical stressors (EPA 1992a). Risks result from contact between ecological receptors and stressors that are of sufficiently long duration and of sufficient intensity to elicit adverse effects (EPA 1992a). The primary purpose of this ERA is to identify and describe actual or potential onsite conditions that can result in adverse effects to present or future ecological receptors. Sufficient recent site-specific information is available to allow this ERA to focus on the primary ecological stressors present at this site. These primary stressors have been identified as polychlorinated biphenyls (PCBs). This ERA focuses on comparing measured or estimated PCB exposures with observed or predicted biological effects. This ERA also provides information that can help establish remedial priorities and serve as a scientific basis for regulatory and remedial actions for the API/PC/KR.

1.2 Report Organization

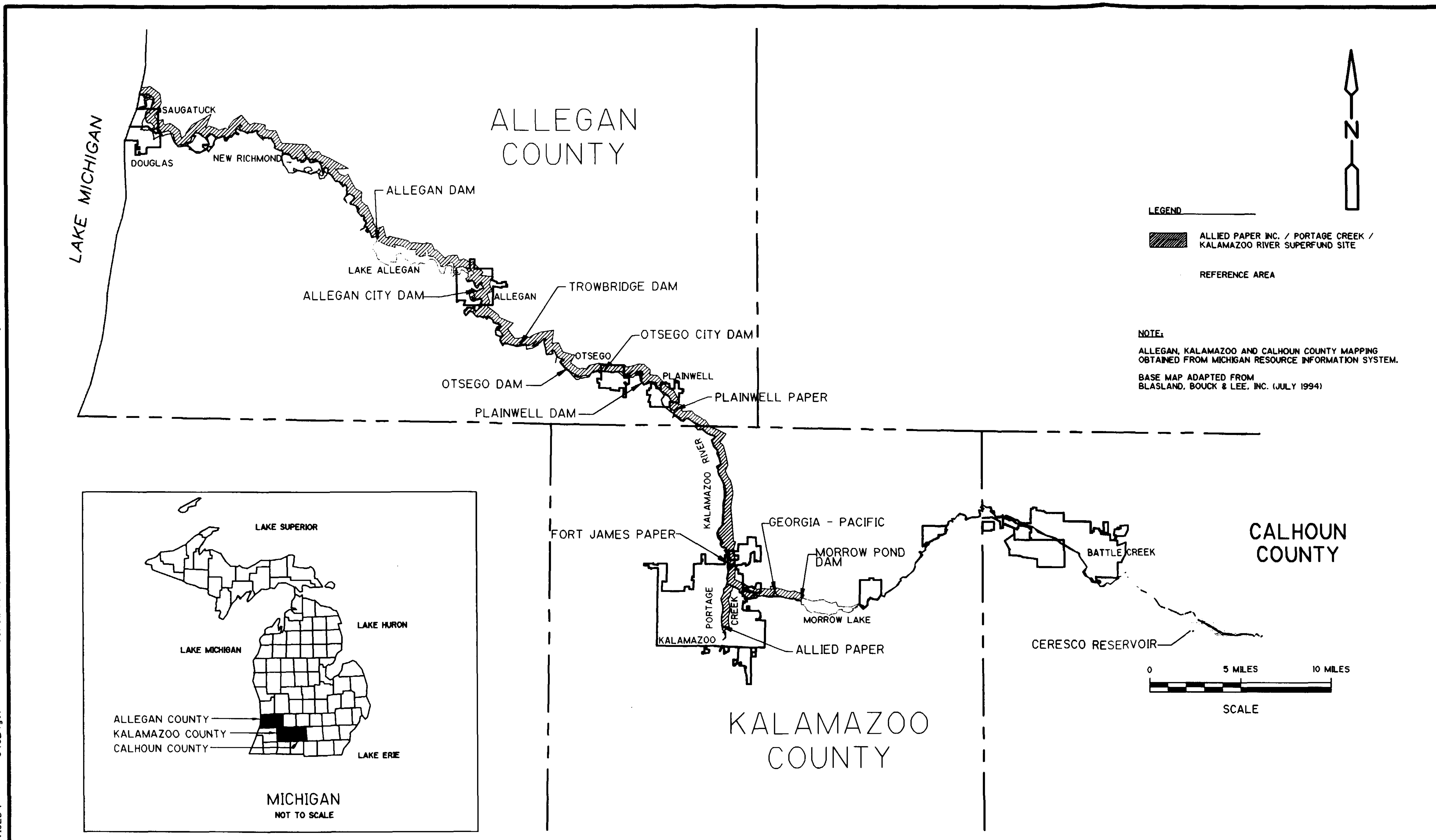
The approach used to conduct this ERA is based on site-specific information and on recent EPA guidance, primarily The Framework for Ecological Risk Assessment (Framework Document, EPA 1992a), supplemented by more recent guidance including the Guidelines for Ecological Risk Assessment (EPA 1998) and Ecological Risk Assessment for Superfund: Process for Designing and conducting Ecological Risk Assessments (EPA 1997). EPA (1989; 1992a, 1997, 1998) and others (e.g., Barnthouse, et al. 1986) recognize that methods for conducting ERAs must be site-specific, and guidance for conducting ERAs are therefore not intended to serve as detailed, specific guidance documents. As much as practicable, the methods, recommendations, and terminology of the Guidelines for Ecological Risk are used to conduct this ERA. The organization of this ERA follows the format presented in this document, with some modifications made for site-specific considerations and readability. Following this introduction, a short description of the site is presented in Section 2. The primary components of this ERA are: Problem Formulation (Section 3) which describes the goals, scope and focus of the ERA; the Analysis Phase (Section 4) which evaluates the data used to assess exposures for local flora and fauna; and the Risk Characterization (Section 5) which discusses the risks identified by this ERA. Additionally, Section 5 describes remedial goals for PCBs in sediments, surface water and floodplain soils associated with the Kalamazoo River. References for all sections are provided in Section 6.

Section 2
Site Description

The Kalamazoo River drainage basin encompasses approximately 2,000 square miles. The main stem of the Kalamazoo River begins in Albion, Michigan at the confluence of the North and South Branches of the Kalamazoo River, and flows northwesterly for 123 miles through Calhoun, Kalamazoo, and Allegan Counties to Lake Michigan at Saugatuck. The Kalamazoo River is fed by more than 400 miles of tributaries, including Portage Creek. Portage Creek begins in Portage, Michigan and including its west fork, flows a distance of approximately 18.5 miles.

Due to the PCB contamination, in August 1990 the site was placed on the National Priorities List (NPL) in accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 1980 PL 96-510 as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 also known as Superfund. The NPL Study Area defined in Michigan Environmental Response Act 307 (also known as the API/KR/PC) includes three miles of Portage Creek, from Cork Street to its confluence with the Kalamazoo River, and 80 miles of the Kalamazoo River, from Morrow Lake Dam downstream to Lake Michigan (**Figure 2-1**). Also included in the site are five paper residual disposal areas and five paper mill properties. Paper residuals (residuals) are the waste material produced by the paper mill during the paper making process. The Michigan Department of Community Health has issued a species specific no consumption fish advisory annually since 1977 for the Kalamazoo River portion of this site due to the PCB contamination. The Kalamazoo River and Portage Creek also have been designated a site of environmental contamination under Part 201, Environmental Remediation, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA), due to PCB contamination. The Kalamazoo River and Portage Creek have been identified as an Area of Concern by the International Joint Commission on the Great Lakes due to the detrimental impact the release of PCBs have on Lake Michigan as well.

The Kalamazoo River is an alternating series of free flowing sections and impoundments formed by low level dams. The Plainwell, Otsego, and Trowbridge Dams have been removed to their sill levels, exposing approximately 507 acres of



ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

KALAMAZOO RIVER ECOLOGICAL RISK ASSESSMENT STUDY AREA

CDM
environmental engineers, scientists, planners, & management consultants

Figure No. 2 - 1

S:\1785\025\clr\REVISED\ 64524g01 06/01/99 09:01:17 14:36:27 Sellgarb former sediments as floodplain soils (Blasland, Bouck & Lee, Inc. 1992). Since these impoundments are all located downstream of the paper mills and landfills which are the PCB sources, they serve as natural sinks for PCB-contaminated sediments. The former dams continue to impound water but to a lesser extent. Michigan Department of Natural Resources (MDNR) owns these three dams and their goal is to remove the remaining structures and return the river to its natural channel. The Otsego City Dam, Allegan City Dam, and the Allegan Lake Dam are still intact. The latter two dams are used to produce hydroelectric power (Blasland, Bouck & Lee, Inc. 1992).

The NPL identified PCBs as the primary contaminant of concern at the API/PC/KR. PCBs were introduced to the environment as a result of using of the river for discharging of waste. The primary industrial activity associated with PCB releases into the API/PC/KR environment was the recycling of PCB-containing carbonless copy paper at several area paper mills. In the process of de-inking and re-pulping recycled paper, paper mills produce substantial quantities of waste residuals. During the period from 1957 to 1971, carbonless copy paper contained PCBs as an ink solvent. Kalamazoo-area paper mills that de-inked or re-pulped the PCB-containing carbonless copy paper thereby incorporated PCBs in their waste streams. These paper mills disposed of their wastes in several ways that resulted in releases of PCBs to the environment, including direct discharge of wastes to Portage Creek and the Kalamazoo River and placement of wastes in disposal areas (landfills) from which PCBs are leached or eroded. The paper wastes also included kaolinite clays which can be signigican sorbents of PCBs primarily as a result of surface area. These clays have been deposited in the API/PC/KR and when concentrated, they appear as spongy, light grey clay layers. In addition, PCBs are persistent in the environment and degradation via chemical oxidation, hydrolysis, and photolysis in soil or aquatic systems is generally insignificant (Blasland, Bouck & Lee, Inc. 1992). PCBs are continually being released to the river from erosion of floodplain soils that exist behind the impounded areas and from instream sediments. Therefore, PCBs are a persistent problem at the API/PC/KR. Similar river systems such as the Fox River (WDNR 1993) and the Hudson River (Brown, et al. 1985) have PCB contaminated sediments that are the major supplier of PCBs to the ecosystem once direct discharges have been eliminated.

Figure 2-1A, in *Description of the Current Situation Report* (Blasland, Bouck & Lee, Inc. 1992) provides a more detailed description of the physical settings and characteristics of the API/PC/KR. Much of the abiotic data used in this ERA, were obtained from this report.

In 1993, Camp Dresser & McKee (CDM) prepared a Biota Sampling Plan (CDM 1993) that outlined sampling activities for the collection of biotic data within the study area. Sampling of biota was conducted to determine current levels of PCBs in resident biota. Based upon these field studies a site-specific model was developed to evaluate bioaccumulation and risk, upon which remedial activities may be based. Field sampling was conducted by Blasland, Bouck & Lee, Inc. with oversight by CDM and the Michigan Department of Environmental Quality (MDEQ) or as by the MDEQ. Biological tissue and corresponding abiotic media data collected in the study area were used in this ecological risk assessment.

Section 3
Problem Formulation

The Problem Formulation phase of this ERA establishes the goals and describes the scope and focus of the assessment. In addition, this phase considers site-specific regulatory and policy issues and requirements and preliminarily identifies potential stressors (Section 3.1) and ecological resources potentially at risk (Section 3.2). The outcome of Problem Formulation is the site-specific conceptual model, which describes potential exposure pathways and the relationship between remedial action objectives, assessment endpoints and measurement endpoints. Endpoints are defined and discussed in Section 3.3, and the site conceptual model is described in Section 3.4.

3.1 Stressor Identification

This ERA is focused on the potential ecological effects associated with PCB contamination of surface water, sediment, surface soil and biota. Current levels of PCB contamination in these media can adversely affect aquatic and terrestrial ecosystems in and adjacent to the API/PC/KR. Other chemical stressors and physical (non-chemical) stressors such as habitat disturbance may also contribute to adverse ecological effects at this site. PCB contamination is considered to be the primary focus of this ERA because of the current magnitude and distribution of PCBs throughout the API/PC/KR (**Figure 2-1**). This ERA does not, therefore, consider the additional incremental effects that may be caused by other chemical stressors. Such effects are likely to be relatively minor compared to the actual or potential effects due to PCB exposures.

Dissolved and particulate-sorbed PCBs occur within and adjacent to the API/PC/KR boundaries. Based on extensive data for this site, the primary chemicals or groups of chemicals of potential concern for the API/PC/KR are PCBs, especially those with higher chlorine (Cl) content such as Aroclor 1016 (40 percent Cl by weight), 1242 (42 percent Cl), 1248 (48 percent Cl), 1254 (54 percent Cl), and 1260 (60 percent Cl). The more highly chlorinated PCBs are environmentally persistent and potentially most hazardous to ecological receptors (Eisler 1986). Most of the measured PCBs at the API/PC/KR are those that are persistent in the environment, such as Aroclors 1242, 1248, 1254, and 1260. Aroclor 1260 is the most commonly found Aroclor found in biological tissue. This ERA is focused on the highly chlorinated PCBs observed in biotic and abiotic media.

Table 3-1
Polychlorinated Biphenyls (PCBs) Detected in API/PC/KR Abotic and Biological Samples

PCBs	Media of Concern
Aroclor 1260	SW, SED, FP SED, SS, BIO
Aroclor 1254	SW, SED, FP SED, SS
Aroclor 1248	SW, SED, FP SED, SS
Aroclor 1242	SW, SED, FP SED, SS
Aroclor 1232	SW, SED, FP SED, SS
Aroclor 1221	SW, SED, FP SED, SS
Aroclor 1016	SW, SED, FP SED, SS

SW:	Surface Water
SED:	Streambed Sediment
FP SED:	Floodplain Sediment (sediments deposited within 100 year floodplain)
SS:	Surface Soil (from soil samples taken from terrestrial biological study areas (TBSAs))
BIO:	Biological tissue

It should be noted that from a regulatory perspective, all PCBs are regulated in Michigan as total PCBs, not as individual PCB congeners. Also, much of the toxicological literature on PCB effects are based on total PCB exposures. Total PCB concentrations, rather than Aroclor- or congener-specific PCB concentrations, are therefore used in this ERA to represent exposure concentrations. Evaluations of potential risk in this ERA are based on total PCB concentrations in abiotic media (e.g., surface water, sediment, surface soil) and biological tissues. **Table 3-1** presents the primary PCBs detected in abiotic and biological samples. The potential ecological effects associated with total PCBs are summarized in Section 4.2.1.

3.2 Ecological Resources Potentially at Risk

This section identifies and describes the major habitats and organisms, or types of organisms that may be exposed to the chemical and physical stressors identified at the API/PC/KR.

3.2.1 Habitat Descriptions

The API/PC/KR ERA is based on data collected from the Kalamazoo River upstream of the City of Battle Creek (upstream reference area) downstream to U.S. Highway 31, east of Lake Michigan (**Figure 2-1**). The area below Allegan Dam is considered to be impacted by current or past upstream PCB sources. The NPL (Superfund) site is the extent of the API/PC/KR including the 100-year floodplain prior to the removal of the Otsego, Plainwell, and Trowbridge Dams down to the sills. The major habitat types within the API/PC/KR — aquatic habitats, riparian habitats/wet-lands and terrestrial habitats — are qualitatively described below.

Aquatic Habitats

Aquatic habitats within the API/PC/KR are found within Portage Creek, the Kalamazoo River and their tributaries. The Kalamazoo River is a large, perennial river that drains a major portion of western Michigan. The API/PC/KR includes approximately 80 river miles. The character of the Kalamazoo River varies from reach to reach. The Kalamazoo River has been influenced by historic flood events and dam construction, operation and removal. Currently, there are areas impacted by fluvially deposited sediments contaminated with anthropogenic chemicals within and adjacent to the river.

Instream substrates consist of variable proportions of the following:

- Boulders (>256 mm or 10 in.)
- Cobble (64 to 256 mm or 2.5 to 10 in.)
- Gravel (2 to 64 mm or 0.1 to 2.5 in.)
- Sand (0.06 to 2.00 mm)
- Silt (0.004 to 0.06 mm)
- Clay (<0.004 mm)
- Organic matter (e.g., leaves, sticks, etc.)

A complete evaluation of particle size distribution of the API/PC/KR bed sediments has not been performed, but the following generalizations adequately describe the major types of API/PC/KR substrates and habitat conditions:

- Former impoundment sites and areas downstream of those subject to erosion are associated with increased siltation and decreased particle size, potentially increasing contaminant loads in these areas.

- Bottom substrates consist of unconsolidated materials, as well as some submerged and emergent vegetation, which may act as sediment traps.

- The relative abundance of potential fish cover (i.e., undercut banks, overhanging vegetation, deep pools, boulders, logs, aquatic vegetation) varies considerably within the API/PC/KR. These areas are especially uncommon within certain sections of the broad floodplain where extensive sediment deposition has occurred.

- Stream channel stability varies with the pattern of annual flooding.

- Areas of suitable habitat for abundant and diverse macroinvertebrate populations (i.e., cobble or gravel substrates with adequate water flow and depth) are uncommon and unevenly distributed throughout the API/PC/KR.

To aid in the evaluation of aquatic habitats and chemical exposure for this ERA, the API/PC/KR is divided into twelve Aquatic Biological Study Areas (ABSAs). Originally ABSAs defined specific locations from which aquatic biota were collected. To describe aquatic habitats and potential exposure areas, these ABSAs were expanded so that they are contiguous, with ABSA boundaries based on physical features such as dam sites or bridges. This approach results in all reaches within the API/PC/KR being associated with a specific ABSA. The expanded ABSAs and associated Terrestrial Biological Study Areas (TBSAs) are described in **Table 3-2.**

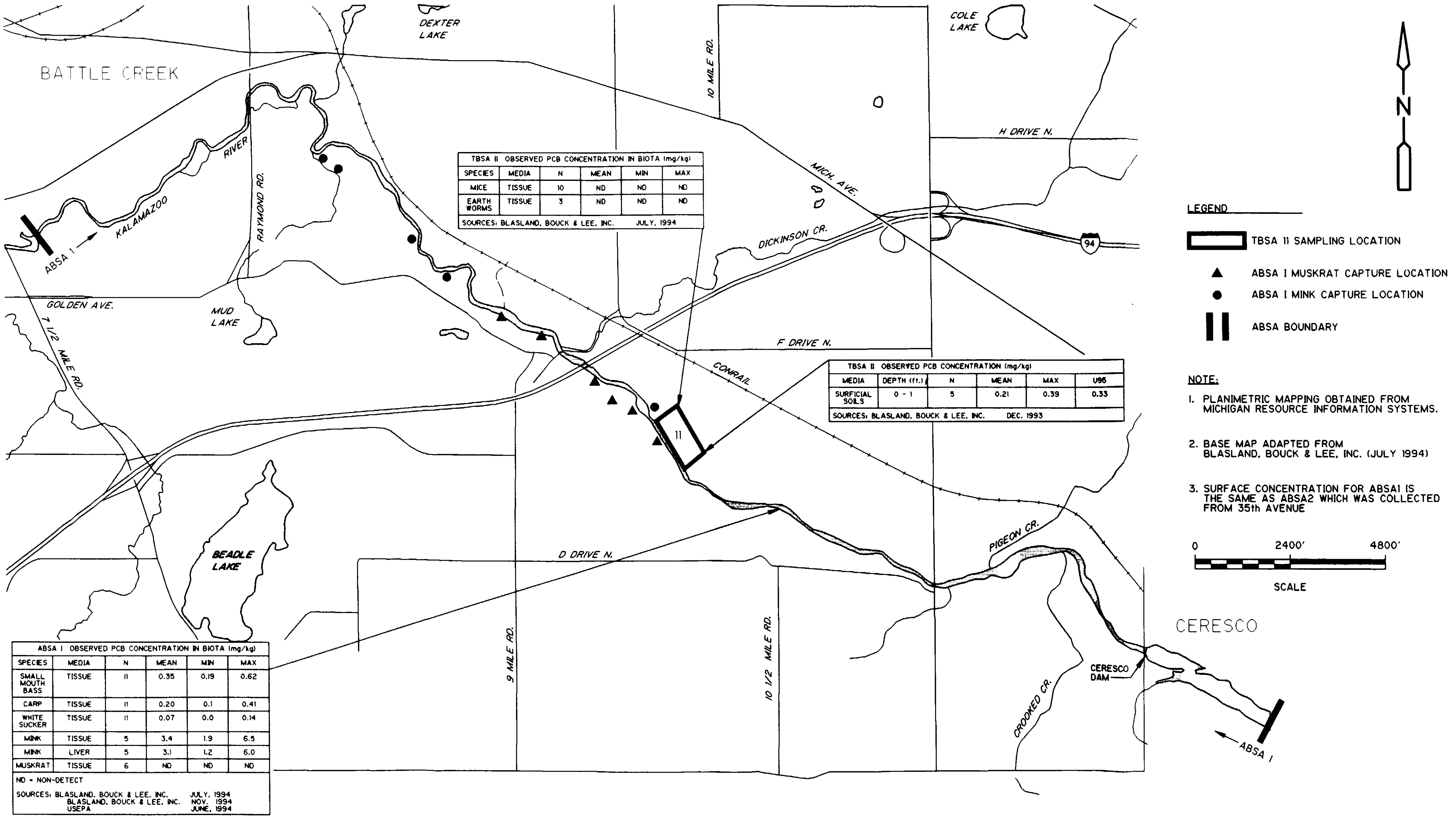
Terrestrial samples (e.g., white-footed/deer mice, earthworms, surface soil) were collected from specific areas within selected ABSAs. Soil sampling identified five acceptable terrestrial biological sampling areas (TBSAs 1, 3, 5, 10, and 11) from which terrestrial samples would be collected.

Each of the ABSAs and TBSAs correspond to particular areas of concern for this ERA. The major areas evaluated in this ERA include:

- Reference area (ABSA 1)
- The Portage Creek area (ABSA 12), which influences ABSA 3 and upstream portions of ABSA 4
- The former Plainwell Impoundment area, which influences the lower portion of ABSA 4 and all of ABSA 5
- The Otsego City Dam impoundment area (ABSA 6)
- The former Otsego Dam impoundment area (ABSA 7)
- The former Trowbridge Dam impoundment area (ABSA 8)
- Lake Allegan (ABSA 9)
- Areas immediately downstream of Lake Allegan that may be impacted by upstream areas (ABSA 10)

Table 3-2
API/PC/KR Biological Study Areas

ABSA 1:	Kalamazoo River upstream of the city of Battle Creek (upstream reference site). Aquatic biota were collected near the I-94 junction with the Kalamazoo River. Includes TBSA 11. (See **Figure 3-1**).
ABSA 2:	Kalamazoo River from the downstream boundary of ABSA 1 to Morrow Lake Dam. Aquatic biota were collected from Morrow Lake. (See **Figure 3-2**).
ABSA 3:	Kalamazoo River from Morrow Dam to Mosel Ave., Kalamazoo. Aquatic biota were collected just downstream of Morrow Dam. (See **Figure 3-2**).
ABSA 4:	Kalamazoo River at Mosel Ave. to Hwy. 131 bridge. Aquatic biota were collected from the Kalamazoo River near Mosel Avenue. (See **Figure 3-3**).
ABSA 5:	Kalamazoo River near Hwy 131 bridge and Plainwell Dam. Aquatic biota were collected from the Kalamazoo River upstream of Plainwell Dam. Includes TBSAs 8, 9 and 10. (See **Figures 3-4**).
ABSA 6:	Kalamazoo River from Plainwell Dam to Otsego City Dam. Aquatic biota were collected from the Kalamazoo River upstream of Otsego City Dam. Includes TBSA 10. (See **Figures 3-5**).
ABSA 7:	Kalamazoo River from Otsego City Dam to Otsego Dam. Aquatic biota were collected just upstream of Otsego Dam. (See **Figure 3-6**).
ABSA 8:	Kalamazoo River from Otsego Dam to Trowbridge Dam. Aquatic biota were collected upstream of Trowbridge Dam. Includes TBSAs 3 and 5. (See **Figures 3-6**).
ABSA 9:	Kalamazoo River from Trowbridge Dam to Lake Allegan Dam. Aquatic biota were collected from Lake Allegan. (See **Figure 3-7**).
ABSA 10:	Kalamazoo River from Lake Allegan Dam to Ottawa Marsh. Aquatic biota were collected downstream of Allegan Dam. Includes TBSA 1. (See **Figure 3-8**).
ABSA 11:	Kalamazoo River from Ottawa Marsh to US 31. Aquatic biota were collected near Saugatuck. (See **Figure 3-9**).
ABSA 12:	Portage Creek (See **Figure 3-10**).



TBSA II OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)

SPECIES	MEDIA	N	MEAN	MIN	MAX
MICE	TISSUE	10	ND	ND	ND
EARTH WORMS	TISSUE	3	ND	ND	ND

SOURCES: BLASLAND, BOUCK & LEE, INC. JULY, 1994

TBSA II OBSERVED PCB CONCENTRATION (mg/kg)

MEDIA	DEPTH (ft.)	N	MEAN	MAX	U95
SURFICIAL SOILS	0 - 1	5	0.21	0.39	0.33

SOURCES: BLASLAND, BOUCK & LEE, INC. DEC. 1993

ABSA I OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)

SPECIES	MEDIA	N	MEAN	MIN	MAX
SMALL MOUTH BASS	TISSUE	11	0.35	0.19	0.62
CARP	TISSUE	11	0.20	0.1	0.41
WHITE SUCKER	TISSUE	11	0.07	0.0	0.14
MINK	TISSUE	5	3.4	1.9	6.5
MINK	LIVER	5	3.1	1.2	6.0
MUSKRAT	TISSUE	6	ND	ND	ND

ND = NON-DETECT

SOURCES: BLASLAND, BOUCK & LEE, INC. JULY, 1994
BLASLAND, BOUCK & LEE, INC. NOV. 1994
USEPA JUNE, 1994

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

KALAMAZOO RIVER ECOLOGICAL RISK ASSESSMENT
OBSERVED PCB CONCENTRATIONS IN AQUATIC & TERRESTRIAL MEDIA
UPSTREAM REFERENCE AREA NEAR BATTLE CREEK

CDM
environmental engineers, scientists, planners, & management consultants

ABSA 1

Figure No. 3 - 1

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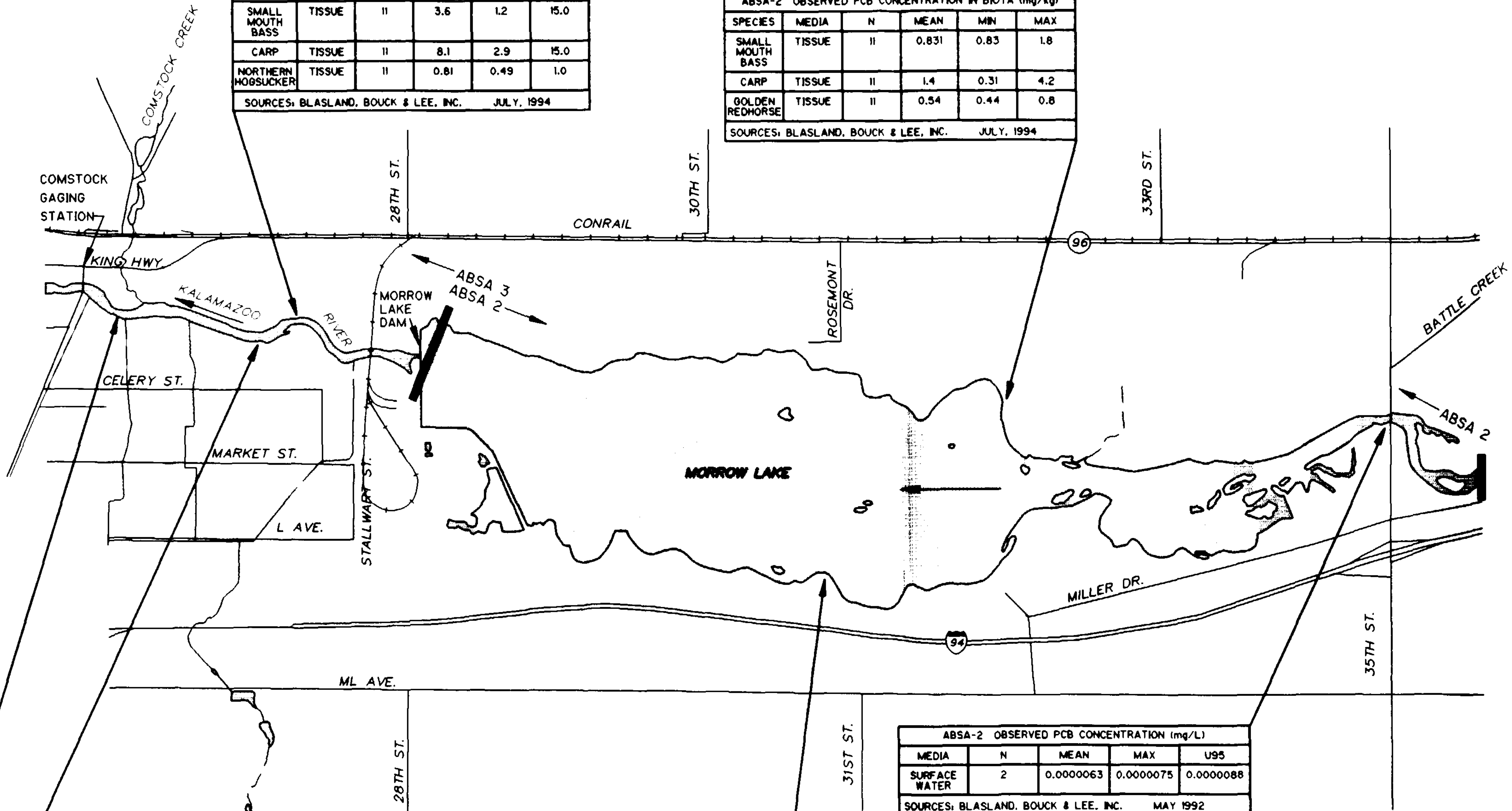
ABSA-3 OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)					
SPECIES	MEDIA	N	MEAN	MIN	MAX
SMALL MOUTH BASS	TISSUE	11	3.6	1.2	15.0
CARP	TISSUE	11	8.1	2.9	15.0
NORTHERN HOGSUCKER	TISSUE	11	0.81	0.49	1.0
SOURCES: BLASLAND, BOUCK & LEE, INC. JULY, 1994					

ABSA-2 OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)					
SPECIES	MEDIA	N	MEAN	MIN	MAX
SMALL MOUTH BASS	TISSUE	11	0.831	0.83	1.8
CARP	TISSUE	11	1.4	0.31	4.2
GOLDEN REDHORSE	TISSUE	11	0.54	0.44	0.8
SOURCES: BLASLAND, BOUCK & LEE, INC. JULY, 1994					



ABSA-2 OBSERVED PCB CONCENTRATION (mg/L)				
MEDIA	N	MEAN	MAX	U95
SURFACE WATER	2	0.0000063	0.0000075	0.0000088
SOURCES: BLASLAND, BOUCK & LEE, INC. MAY 1992				

ABSA-3 OBSERVED PCB CONCENTRATION (mg/L)				
MEDIA	N	MEAN	MAX	U95
SURFACE WATER	30	0.000015	0.000048	0.000019
SOURCES: BLASLAND, BOUCK & LEE, INC. MARCH 1995				

ABSA-2 OBSERVED PCB CONCENTRATION (mg/kg)				
MEDIA	N	MEAN	MAX	U95
SEDIMENTS	20	0.91	2.4	1.2
SOURCES: BLASLAND, BOUCK & LEE, INC. MAY 1995				

ABSA-3 OBSERVED PCB CONCENTRATION (mg/kg)				
MEDIA	N	MEAN	MAX	U95
SEDIMENTS	40	2.3	86	6.5
SOURCES: BLASLAND, BOUCK & LEE, INC. APRIL 1994				

LEGEND

ABSA BOUNDARIES

NOTE:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. SAMPLING AREAS APPROXIMATED BY BLASLAND, BOUCK & LEE, INC.
3. BASE MAP ADAPTED FROM BLASLAND, BOUCK & LEE, INC. (JULY 1994)

0 2400′ 4800′

SCALE:

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

KALAMAZOO RIVER ECOLOGICAL RISK ASSESSMENT
OBSERVED PCB CONCENTRATIONS IN AQUATIC MEDIA
MORROW LAKE AREA

ABSA 2
ABSA 3

Figure No. 3 - 2

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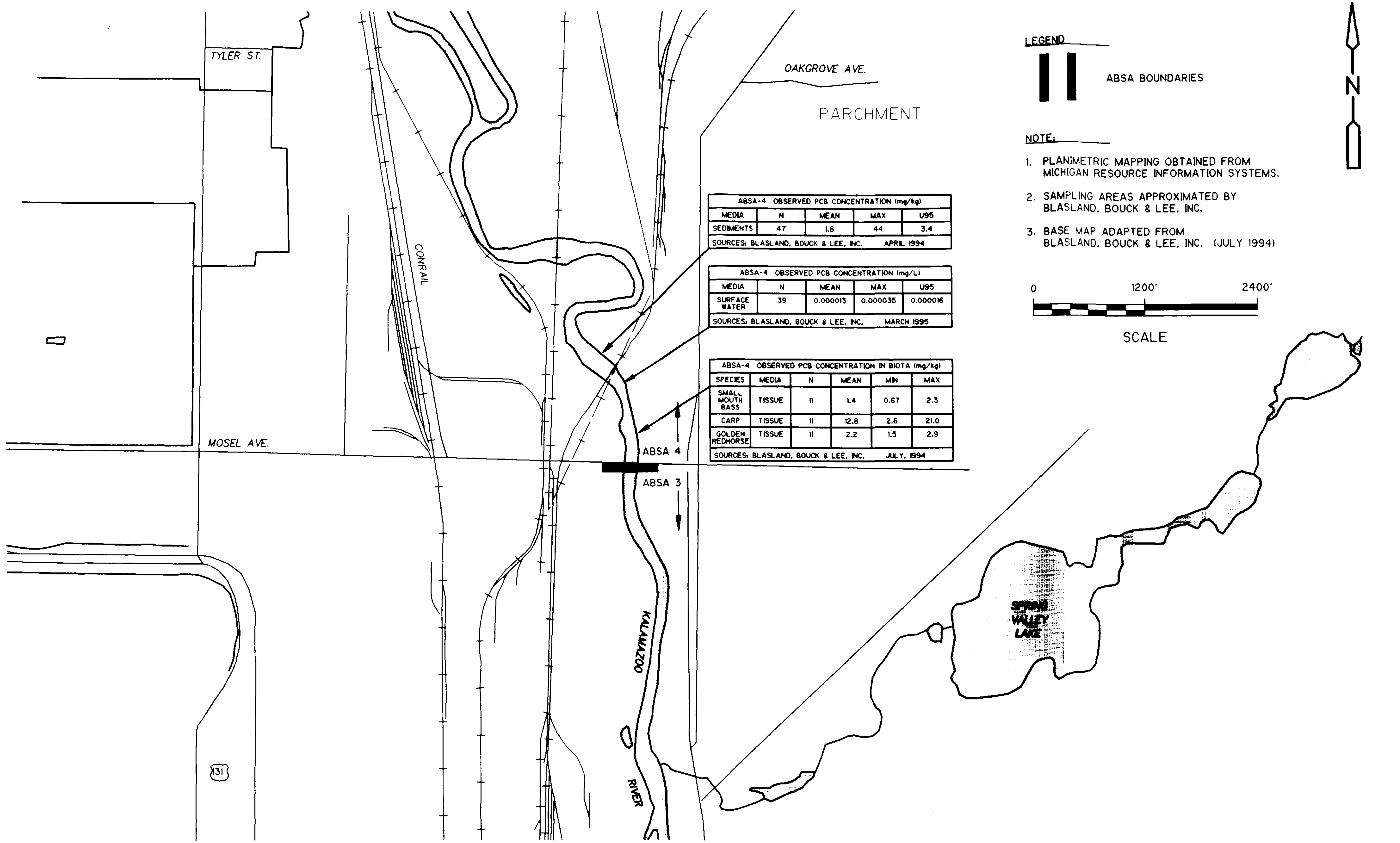

ABSA-4 OBSERVED PCB CONCENTRATION (mg/kg)

MEDIA	N	MEAN	MAX	U95
SEDIMENTS	47	1.6	44	3.4

SOURCES: BLASLAND, BOUCK & LEE, INC. APRIL 1994

ABSA-4 OBSERVED PCB CONCENTRATION (mg/L)

MEDIA	N	MEAN	MAX	U95
SURFACE WATER	39	0.000013	0.000035	0.000016

SOURCES: BLASLAND, BOUCK & LEE, INC. MARCH 1995

ABSA-4 OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)

SPECIES	MEDIA	N	MEAN	MIN	MAX
SMALL MOUTH BASS	TISSUE	11	1.4	0.67	2.3
CARP	TISSUE	11	12.8	2.6	21.0
GOLDEN REDHORSE	TISSUE	11	2.2	1.5	2.9

SOURCES: BLASLAND, BOUCK & LEE, INC. JULY, 1994

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

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KALAMAZOO RIVER ECOLOGICAL RISK ASSESSMENT
OBSERVED PCB CONCENTRATIONS IN AQUATIC MEDIA
MOSEL AVENUE AREA

ABSA 4
ABSA 3

Figure No. 3 - 3

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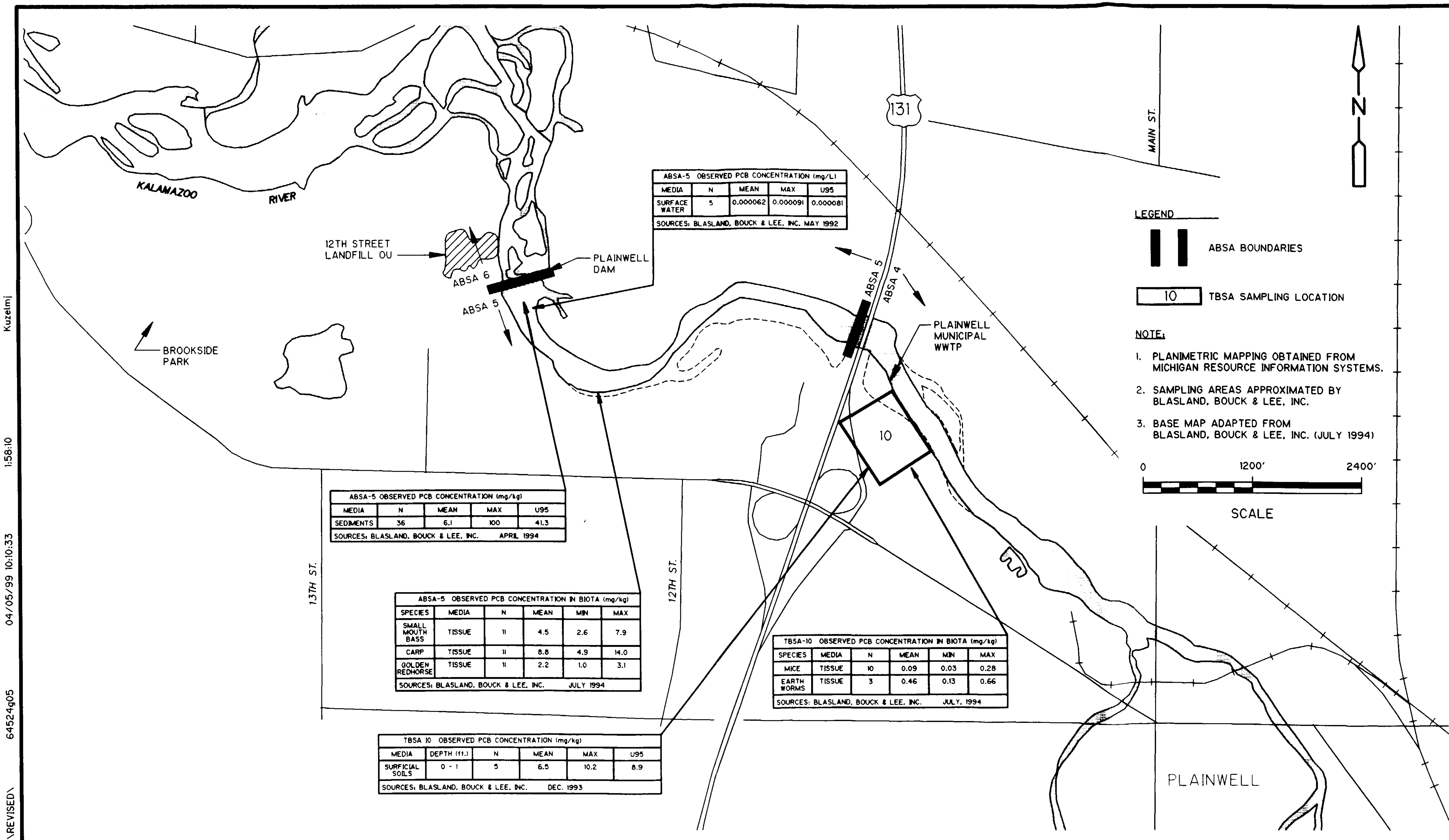

ABSA-5 OBSERVED PCB CONCENTRATION (mg/L)

MEDIA	N	MEAN	MAX	U95
SURFACE WATER	5	0.000062	0.000091	0.000081

SOURCES: BLASLAND, BOUCK & LEE, INC. MAY 1992

ABSA-5 OBSERVED PCB CONCENTRATION (mg/kg)

MEDIA	N	MEAN	MAX	U95
SEDIMENTS	36	6.1	100	41.3

SOURCES: BLASLAND, BOUCK & LEE, INC. APRIL 1994

ABSA-5 OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)

SPECIES	MEDIA	N	MEAN	MIN	MAX
SMALL MOUTH BASS	TISSUE	11	4.5	2.6	7.9
CARP	TISSUE	11	8.8	4.9	14.0
GOLDEN REDHORSE	TISSUE	11	2.2	1.0	3.1

SOURCES: BLASLAND, BOUCK & LEE, INC. JULY 1994

TBSA-10 OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)

SPECIES	MEDIA	N	MEAN	MIN	MAX
MICE	TISSUE	10	0.09	0.03	0.28
EARTH WORMS	TISSUE	3	0.46	0.13	0.66

SOURCES: BLASLAND, BOUCK & LEE, INC. JULY, 1994

TBSA 10 OBSERVED PCB CONCENTRATION (mg/kg)

MEDIA	DEPTH (ft.)	N	MEAN	MAX	U95
SURFICIAL SOILS	0 - 1	5	6.5	10.2	8.9

SOURCES: BLASLAND, BOUCK & LEE, INC. DEC. 1993

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

KALAMAZOO RIVER ECOLOGICAL RISK ASSESSMENT
OBSERVED PCB CONCENTRATIONS IN AQUATIC AND TERRESTRIAL MEDIA
UPSTREAM OF PLAINWELL DAM

ABSA 4
ABSA 5

Figure No. 3 - 4

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ABSA-6 OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)

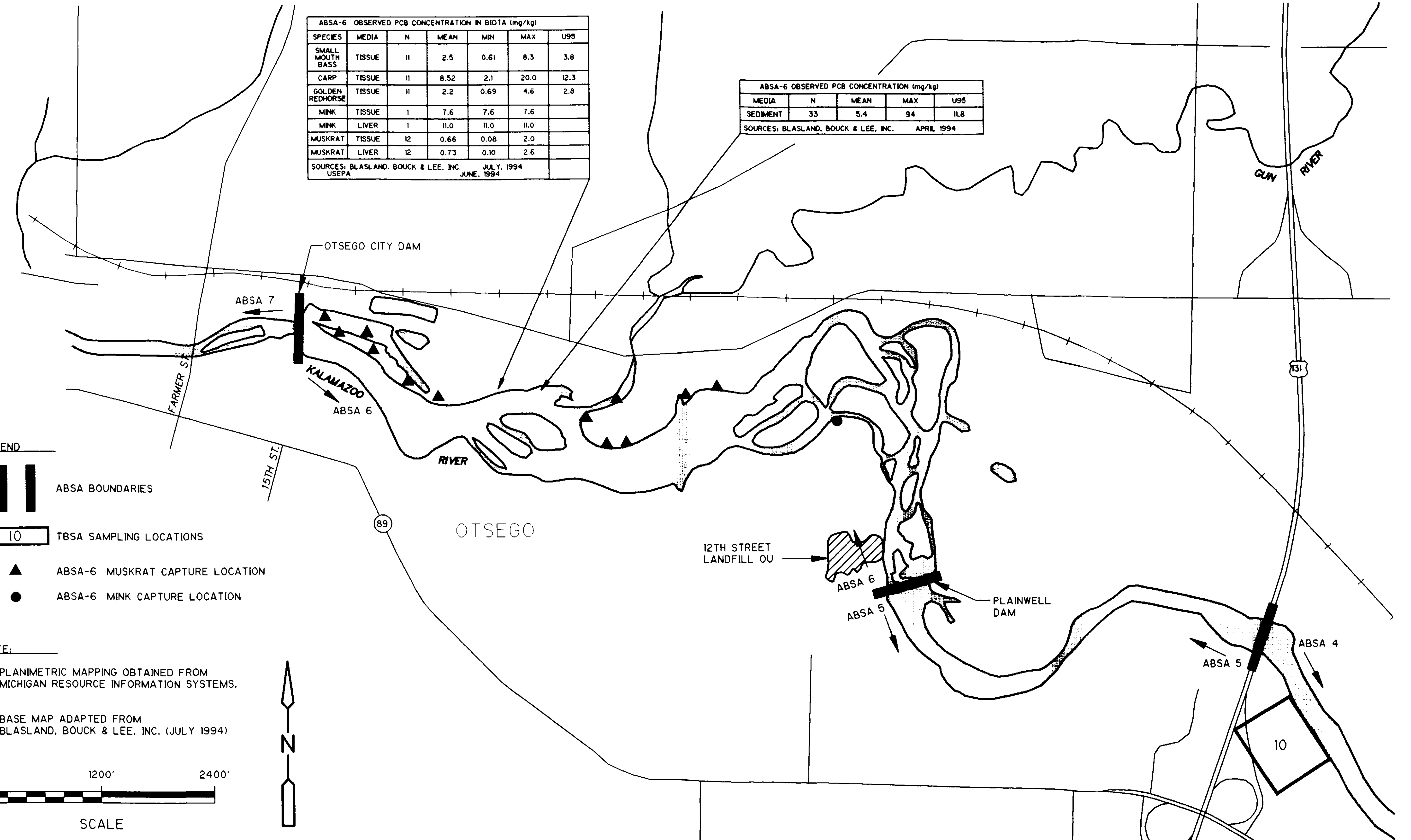
SPECIES	MEDIA	N	MEAN	MIN	MAX	U95
SMALL MOUTH BASS	TISSUE	11	2.5	0.61	8.3	3.8
CARP	TISSUE	11	8.52	2.1	20.0	12.3
GOLDEN REDHORSE	TISSUE	11	2.2	0.69	4.6	2.8
MINK	TISSUE	1	7.6	7.6	7.6	
MINK	LIVER	1	11.0	11.0	11.0	
MUSKRAT	TISSUE	12	0.66	0.08	2.0	
MUSKRAT	LIVER	12	0.73	0.10	2.6	

SOURCES: BLASLAND, BOUCK & LEE, INC. JULY, 1994
USEPA JUNE, 1994

ABSA-6 OBSERVED PCB CONCENTRATION (mg/kg)

MEDIA	N	MEAN	MAX	U95
SEDIMENT	33	5.4	94	11.8

SOURCES: BLASLAND, BOUCK & LEE, INC. APRIL 1994



LEGEND

ABSA BOUNDARIES

10 TBSA SAMPLING LOCATIONS

ABSA-6 MUSKRAT CAPTURE LOCATION

ABSA-6 MINK CAPTURE LOCATION

NOTE:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. BASE MAP ADAPTED FROM BLASLAND, BOUCK & LEE, INC. (JULY 1994)

0 1200′ 2400′

SCALE

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

KALAMAZOO RIVER ECOLOGICAL RISK ASSESSMENT
OBSERVED PCB CONCENTRATIONS IN AQUATIC & TERRESTRIAL MEDIA
BETWEEN OF OTSEGO CITY DAM AND PLAINWELL DAM

CDM
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ABSA 5
ABSA 6

Figure No. 3 - 5

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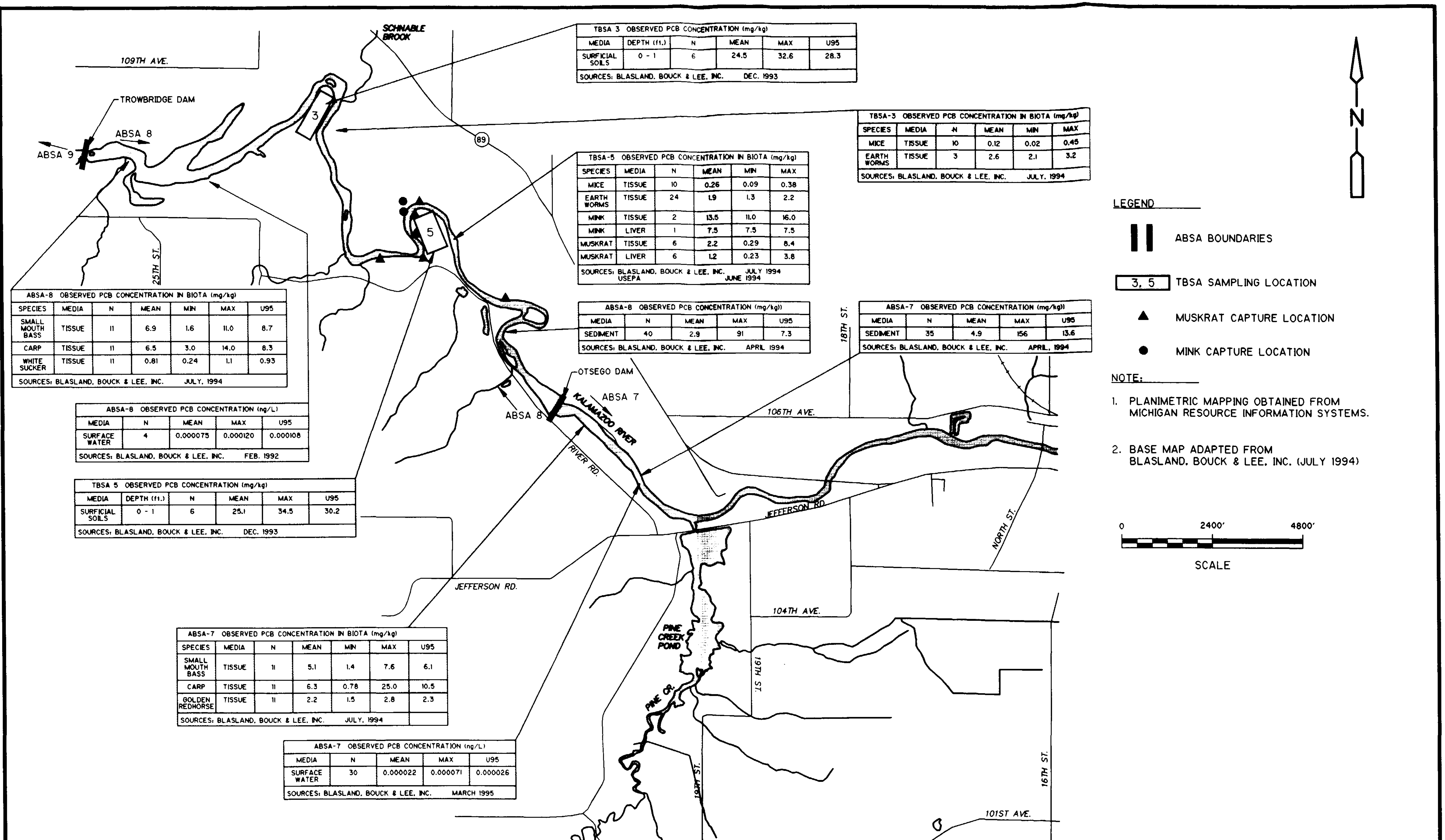

TBSA 3 OBSERVED PCB CONCENTRATION (mg/kg)

MEDIA	DEPTH (ft.)	N	MEAN	MAX	U95
SURFICIAL SOILS	0 - 1	6	24.5	32.6	28.3
SOURCES: BLASLAND, BOUCK & LEE, INC. DEC. 1993					

TBSA-3 OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)

SPECIES	MEDIA	N	MEAN	MIN	MAX
MICE	TISSUE	10	0.12	0.02	0.45
EARTH WORMS	TISSUE	3	2.6	2.1	3.2
SOURCES: BLASLAND, BOUCK & LEE, INC. JULY, 1994					

TBSA-5 OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)

SPECIES	MEDIA	N	MEAN	MIN	MAX
MICE	TISSUE	10	0.26	0.09	0.38
EARTH WORMS	TISSUE	24	1.9	1.3	2.2
MINK	TISSUE	2	13.5	11.0	16.0
MINK	LIVER	1	7.5	7.5	7.5
MUSKRAT	TISSUE	6	2.2	0.29	8.4
MUSKRAT	LIVER	6	1.2	0.23	3.8
SOURCES: BLASLAND, BOUCK & LEE, INC. JULY 1994 USEPA JUNE 1994					

ABSA-8 OBSERVED PCB CONCENTRATION (mg/kg))

MEDIA	N	MEAN	MAX	U95
SEDIMENT	40	2.9	91	7.3
SOURCES: BLASLAND, BOUCK & LEE, INC. APRIL 1994				

ABSA-7 OBSERVED PCB CONCENTRATION (mg/kg))

MEDIA	N	MEAN	MAX	U95
SEDIMENT	35	4.9	156	13.6
SOURCES: BLASLAND, BOUCK & LEE, INC. APRIL, 1994				

ABSA-8 OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)

SPECIES	MEDIA	N	MEAN	MIN	MAX	U95
SMALL MOUTH BASS	TISSUE	11	6.9	1.6	11.0	8.7
CARP	TISSUE	11	6.5	3.0	14.0	8.3
WHITE SUCKER	TISSUE	11	0.81	0.24	1.1	0.93
SOURCES: BLASLAND, BOUCK & LEE, INC. JULY, 1994						

ABSA-8 OBSERVED PCB CONCENTRATION (ng/L)

MEDIA	N	MEAN	MAX	U95
SURFACE WATER	4	0.000075	0.000120	0.000108
SOURCES: BLASLAND, BOUCK & LEE, INC. FEB. 1992				

TBSA 5 OBSERVED PCB CONCENTRATION (mg/kg)

MEDIA	DEPTH (ft.)	N	MEAN	MAX	U95
SURFICIAL SOILS	0 - 1	6	25.1	34.5	30.2
SOURCES: BLASLAND, BOUCK & LEE, INC. DEC. 1993					

ABSA-7 OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)

SPECIES	MEDIA	N	MEAN	MIN	MAX	U95
SMALL MOUTH BASS	TISSUE	11	5.1	1.4	7.6	6.1
CARP	TISSUE	11	6.3	0.78	25.0	10.5
GOLDEN REDHORSE	TISSUE	11	2.2	1.5	2.8	2.3
SOURCES: BLASLAND, BOUCK & LEE, INC. JULY, 1994						

ABSA-7 OBSERVED PCB CONCENTRATION (ng/L)

MEDIA	N	MEAN	MAX	U95
SURFACE WATER	30	0.000022	0.000071	0.000026
SOURCES: BLASLAND, BOUCK & LEE, INC. MARCH 1995				

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

KALAMAZOO RIVER ECOLOGICAL RISK ASSESSMENT
OBSERVED PCB CONCENTRATIONS IN AQUATIC & TERRESTRIAL MEDIA
TROWBRIDGE DAM AREA UPSTREAM TO OTSEGO

CDM
environmental engineers, scientists, planners, & management consultants

ABSA 7
ABSA 8

Figure No. 3 - 6

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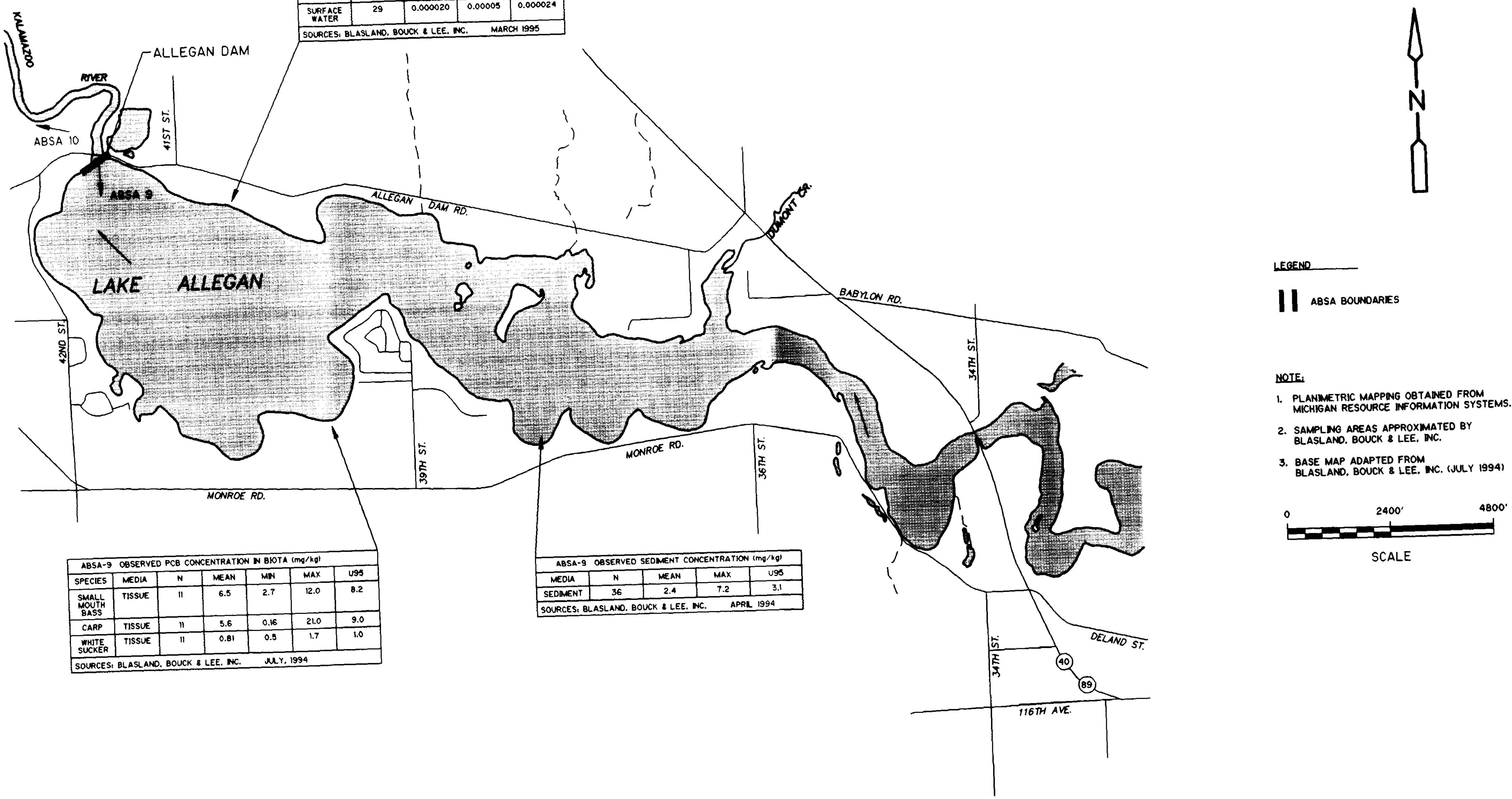

ABSA-9 OBSERVED PCB CONCENTRATION (ng/L)

MEDIA	N	MEAN	MAX	U95
SURFACE WATER	29	0.000020	0.00005	0.000024

SOURCES: BLASLAND, BOUCK & LEE, INC. MARCH 1995

ABSA-9 OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)

SPECIES	MEDIA	N	MEAN	MIN	MAX	U95
SMALL MOUTH BASS	TISSUE	11	6.5	2.7	12.0	8.2
CARP	TISSUE	11	5.6	0.16	21.0	9.0
WHITE SUCKER	TISSUE	11	0.81	0.5	1.7	1.0

SOURCES: BLASLAND, BOUCK & LEE, INC. JULY, 1994

ABSA-9 OBSERVED SEDIMENT CONCENTRATION (mg/kg)

MEDIA	N	MEAN	MAX	U95
SEDIMENT	36	2.4	7.2	3.1

SOURCES: BLASLAND, BOUCK & LEE, INC. APRIL 1994

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ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

KALAMAZOO RIVER ECOLOGICAL RISK ASSESSMENT
OBSERVED PCB CONCENTRATIONS IN AQUATIC MEDIA
LAKE ALLEGAN

ABSA 9

Figure No. 3 - 7

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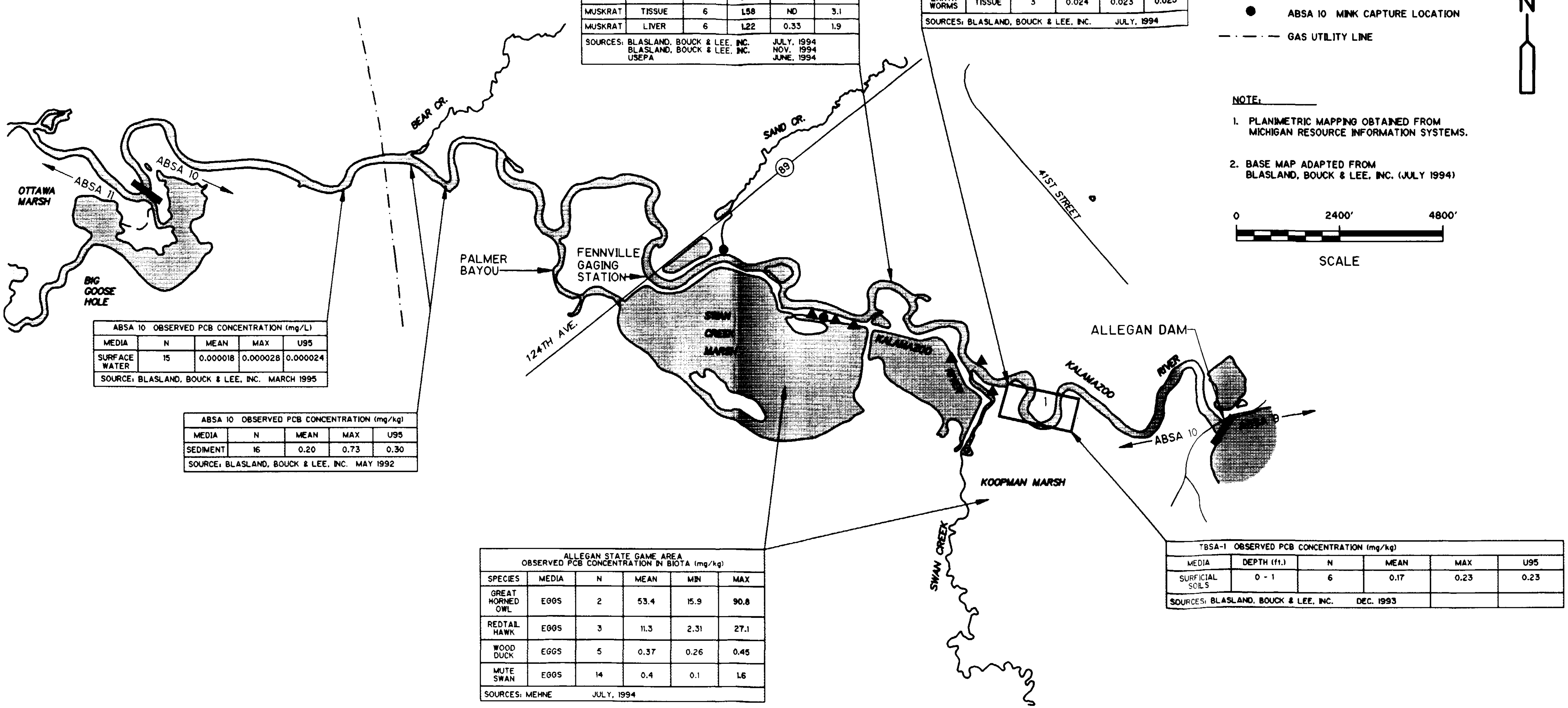

ABSA 10 OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)

SPECIES	MEDIA	N	MEAN	MIN	MAX	U95
SMALL MOUTH BASS	TISSUE	11	5.6	2.6	8.4	6.8
CARP	TISSUE	11	13.2	2.5	36.0	19.1
SPOTTED SUCKER	TISSUE	11	0.35	0.13	0.92	0.49
MINK	TISSUE	2	8.6	5.2	12.0	
MINK	LIVER	2	30.5	8.9	52.0	
MUSKRAT	TISSUE	6	1.58	ND	3.1	
MUSKRAT	LIVER	6	1.22	0.33	1.9	

SOURCES: BLASLAND, BOUCK & LEE, INC. JULY, 1994
BLASLAND, BOUCK & LEE, INC. NOV. 1994
USEPA JUNE, 1994

TBSA-1 OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)

SPECIES	MEDIA	N	MEAN	MIN	MAX
MICE	TISSUE	10	0.067	0.011	0.035
EARTH WORMS	TISSUE	3	0.024	0.023	0.025

SOURCES: BLASLAND, BOUCK & LEE, INC. JULY, 1994

ABSA 10 OBSERVED PCB CONCENTRATION (mg/L)

MEDIA	N	MEAN	MAX	U95
SURFACE WATER	15	0.000018	0.000028	0.000024

SOURCE: BLASLAND, BOUCK & LEE, INC. MARCH 1995

ABSA 10 OBSERVED PCB CONCENTRATION (mg/kg)

MEDIA	N	MEAN	MAX	U95
SEDIMENT	16	0.20	0.73	0.30

SOURCE: BLASLAND, BOUCK & LEE, INC. MAY 1992

ALLEGAN STATE GAME AREA
OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)

SPECIES	MEDIA	N	MEAN	MIN	MAX
GREAT HORNED OWL	EGGS	2	53.4	15.9	90.8
REDTAIL HAWK	EGGS	3	11.3	2.31	27.1
WOOD DUCK	EGGS	5	0.37	0.26	0.45
MUTE SWAN	EGGS	14	0.4	0.1	1.6

SOURCES: MEHNE JULY, 1994

TBSA-1 OBSERVED PCB CONCENTRATION (mg/kg)

MEDIA	DEPTH (ft.)	N	MEAN	MAX	U95
SURFICIAL SOILS	0 - 1	6	0.17	0.23	0.23

SOURCES: BLASLAND, BOUCK & LEE, INC. DEC. 1993

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

KALAMAZOO RIVER ECOLOGICAL RISK ASSESSMENT
OBSERVED PCB CONCENTRATIONS IN AQUATIC AND TERRESTRIAL MEDIA
DOWNSTREAM OF ALLEGAN DAM

ABSA 10

Figure No. 3 - 8

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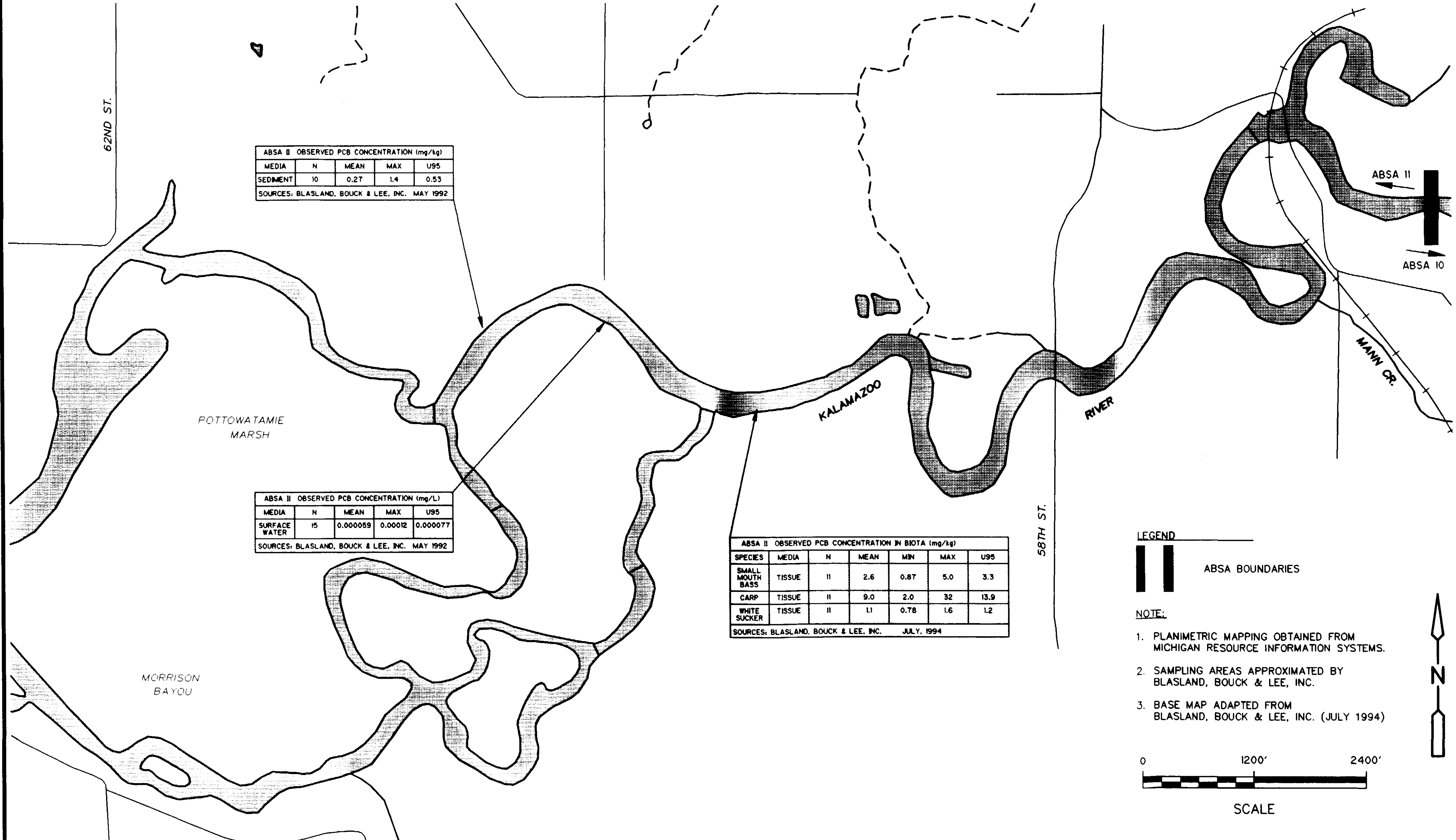

ABSA 11 OBSERVED PCB CONCENTRATION (mg/kg)				
MEDIA	N	MEAN	MAX	U95
SEDIMENT	10	0.27	1.4	0.53
SOURCES: BLASLAND, BOUCK & LEE, INC. MAY 1992				

ABSA 11 OBSERVED PCB CONCENTRATION (mg/L)				
MEDIA	N	MEAN	MAX	U95
SURFACE WATER	15	0.000059	0.00012	0.000077
SOURCES: BLASLAND, BOUCK & LEE, INC. MAY 1992				

ABSA 11 OBSERVED PCB CONCENTRATION IN BIOTA (mg/kg)						
SPECIES	MEDIA	N	MEAN	MIN	MAX	U95
SMALL MOUTH BASS	TISSUE	11	2.6	0.87	5.0	3.3
CARP	TISSUE	11	9.0	2.0	32	13.9
WHITE SUCKER	TISSUE	11	1.1	0.78	1.6	1.2
SOURCES: BLASLAND, BOUCK & LEE, INC. JULY, 1994						

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

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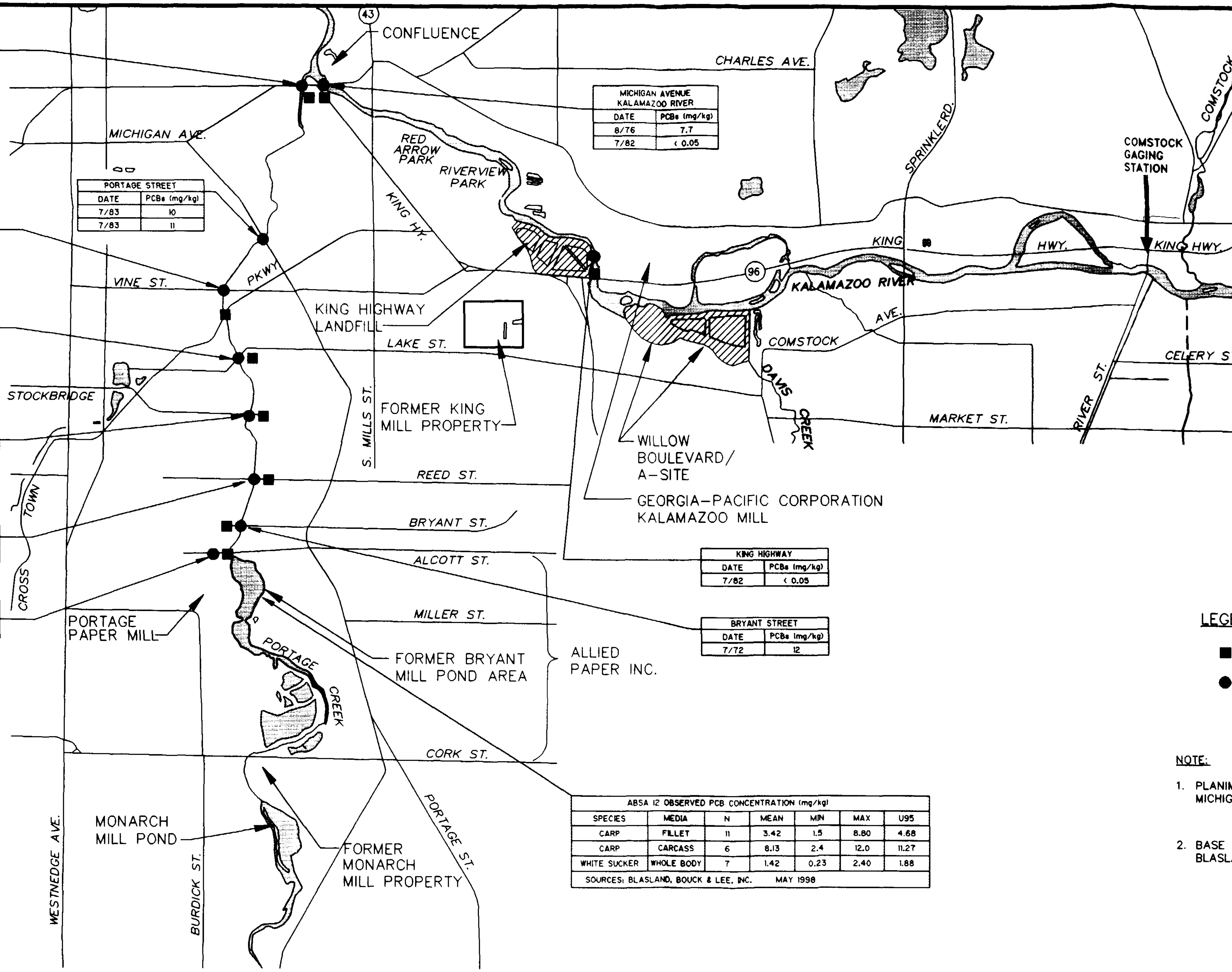
KALAMAZOO RIVER ECOLOGICAL RISK ASSESSMENT
OBSERVED PCB CONCENTRATIONS IN AQUATIC MEDIA
POTTOWATAMIE MARSH AREA

ABSA 11

Figure No. 3 - 9



MICHIGAN AVENUE PORTAGE CREEK	
DATE	PCBs (mg/kg)
8/76	0.50
11/72	85
7/83	15
7/83	15
7/83	15

PORTAGE STREET	
DATE	PCBs (mg/kg)
7/83	10
7/83	11

VINE STREET	
DATE	PCBs (mg/kg)
8/76	56
1976	56

LAKE STREET	
DATE	PCBs (mg/kg)
7/72	25
7/72	12
1972	120

STOCKBRIDGE AVENUE	
DATE	PCBs (mg/kg)
7/72	19

REED AVENUE	
DATE	PCBs (mg/kg)
7/72	25

ALCOTT STREET	
DATE	PCBs (mg/kg)
7/72	26

MICHIGAN AVENUE KALAMAZOO RIVER	
DATE	PCBs (mg/kg)
8/76	7.7
7/82	< 0.05

KING HIGHWAY	
DATE	PCBs (mg/kg)
7/82	< 0.05

BRYANT STREET	
DATE	PCBs (mg/kg)
7/72	12

ABSA 12 OBSERVED PCB CONCENTRATION (mg/kg)						
SPECIES	MEDIA	N	MEAN	MIN	MAX	U95
CARP	FILLET	11	3.42	1.5	8.80	4.68
CARP	CARCASS	6	8.13	2.4	12.0	11.27
WHITE SUCKER	WHOLE BODY	7	1.42	0.23	2.40	1.88
SOURCES: BLASLAND, BOUCK & LEE, INC. MAY 1998						

LEGEND

- ■ WATER COLUMN SAMPLE
- ● SURFACE SEDIMENT SAMPLE (mg/kg) (CONCENTRATION)

NOTE:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. BASE MAP ADAPTED FROM BLASLAND, BOUCK & LEE, INC. (FEB, 1991)

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ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

KALAMAZOO RIVER ECOLOGICAL RISK ASSESSMENT
OBSERVED PCB CONCENTRATIONS IN AQUATIC & TERRESTRIAL MEDIA
PORTAGE CREEK AREA

ABSA 12

Figure No. 3 - 10

Impacts to each of these areas of concern are evaluated in this ERA on a ABSA-specific basis. In the Risk Characterization phase of the ERA, the ecological significance of ABSA-specific impacts to each of the major areas of concern are evaluated.

Riparian Habitats/Wetlands

Riparian habitats exist adjacent to the watercourse of the Kalamazoo River and Portage Creek. Riparian habitats include both upland and wetland habitats within the floodplain of the river. Native floodplain soils are composed of fluvially deposited silts, fine to coarse sands, and gravels of varying sizes. In certain areas, these floodplain soils are overladen with contaminated fine-grained sediments.

Numerous wetlands are identified within the API/PC/KR, and these provide diverse and abundant vegetation and habitat for a wide variety of aquatic and riparian/terrestrial species dependent on aquatic ecosystems. These areas are, therefore, important for the health and status of several types of terrestrial as well as aquatic biota.

In general, wetlands occur throughout the API/PC/KR and are dominated by a large variety of perennial grasses, shrubs, and trees common to western Michigan. See **Appendix A** for a detailed list of plant species. Outside of industrial or residential areas, there does not appear to be substantial differences in the diversity and abundance of riparian plants from one ABSA to another.

Terrestrial Habitats

Terrestrial habitats beyond the riparian areas adjacent to the API/PC/KR include relatively flat open areas with varying amounts of vegetative cover, some of which are used for grazing cattle. Also nearby are low rolling hills that are mostly thickly wooded and densely shaded. Terrestrial habitats in the API/PC/KR are also found in portions of residential and industrial areas and represent ecological islands within urban areas.

3.2.2 Impacts to Ecological Resources

The API/PC/KR corridor supports a large variety of ecological resources (Section 3.2.3). This ERA is focused on addressing the impacts of PCB contamination to surface water, streambed sediments, floodplain sediments, and surficial soils, as well as biota that are adversely affected by ingestion of PCB-contaminated food items, resulting in increased levels of bioaccumulation of PCBs in higher trophic levels. **Figures 3-1** through **3-10** show the results of observed PCB concentrations in various aquatic/semi-aquatic (surface water, fish, mink, muskrat, streambed sediments) and terrestrial (mice, earthworms, surfical soils) media that were sampled in the defined ASBAs and TBSAs in accordance with the API/PC/KR Biota Sampling Plan (CDM, 1993). Each Figure provides the number of samples collected, and the mean, minimum, and maximum PCB concentrations observed in individual media for each ABSA or TBSA. Section 5, Risk Characterization, addresses the risks associated with the observed PCB contamination at the API/PC/KR.

3.2.3 Identification of Potential Receptors

Potential ecological receptors for this study are defined as plants and animals (i.e., macroinvertebrates, fish, amphibians, reptiles, birds, and mammals) that inhabit or use, or have potential to inhabit or use, the aquatic, riparian/wetland and terrestrial habitats of the API/PC/KR. Although other organisms such as bacteria, protozoans, and fungi are essential components of aquatic and terrestrial ecosystems, potential impacts to these organisms are not assessed in this ERA because adequate data are unavailable for such an assessment.

Field surveys conducted by CDM and others revealed a large variety of plant and animal species utilizing all available habitat types in the study area. Studies were not conducted specifically to evaluate relative abundance or diversity of plant and animal species resident to or using the API/PC/KR. In general, however, a large variety of plant and animal species expected in the area were observed during field work conducted in support of the ERA (See **Appendix A**).

Several plant and animal species of special concern have potential to exist in the study area (**Appendix A**), including threatened, endangered, and sensitive species such as white false indigo, bald eagle, great blue heron and eastern box turtle. Bald eagles do nest within the lower reaches the API/PC/KR, and great blue hurons have an established herony along the Kalamazoo River downstream of Lake Allegan. **Appendix A** also provides lists of invertebrates, fish, amphibians, reptiles, birds and mammals that are found in this part of Michigan. All of these species have potential to occur within the API/PC/KR.

Major species, including local subspecies, or types of organisms that have been observed onsite, expected to inhabit or use the API/PC/KR environs, or have potential to inhabit or use the area are described below. The species lists, presented in **Appendix A**, do not identify every plant or invertebrate that occurs or might occur onsite, but instead include observed species and representatives of major groups of these organisms that may occur onsite. Vertebrate species, including subspecies if applicable, that (1) have been observed onsite, (2) are likely to occur onsite, or (3) have potential to occur onsite, are considered potential receptors and are therefore included in the species lists provided. The potential to inhabit or use the API/PC/KR is based on published geographical ranges, general habitat requirements, comparison to nearby reference areas and, in some cases, the remediation of critical chemical or physical stressors.

The large number of potential receptor species identified for the API/PC/KR obviously precludes an assessment of potential risks for every species listed. Several species or groups of organisms have therefore been selected to serve as representative receptors for a detailed evaluation of potential risks. The selection of these receptors is based on (1) their perceived importance to local ecosystems (e.g., key prey species), (2) their population status, (3) their relationship with human use (e.g., game species), (4) the size of their home range in relation to the area, (5) sensitivity to PCBs, and (6) the availability of data for assessing potential risk. Using these criteria, the following nine groups of organisms are selected as final ecological receptors for the API/PC/KR.

- *Aquatic Plants*
  Primary producers in aquatic ecosystems; can be important food items for zooplankton and other invertebrates which, in turn, are preyed upon by small/young fish and other aquatic life; potentially abundant; potential for high biomass; (e.g., algae).

- *Aquatic Macroinvertebrates*
  Important prey species for many gamefish; potentially abundant; potential for high biomass; (e.g., larval midges, mayflies, stoneflies, caddisflies; amphipods).

- *Freshwater Game Fish*
  Potential for high biomass; significant relationship with human use; (e.g., smallmouth bass and salmonids).

- *Freshwater Forage Fish*
  Potential for high biomass; likely to be significant prey item for piscivorous predators, including game fish; (e.g., white sucker).

- *Freshwater Rough Fish*
  Potential for high biomass; likely to be significant prey item for piscivorous predators, including mink; intimate contact with potentially contaminated sediment; (e.g., common carp).

- ***Terrestrial Invertebrates***
  Abundant; important prey species for shrews, birds, toads, etc.; (e.g., earthworms).

- ***Small Burrowing Terrestrial and Semi-aquatic Mammals***
  Abundant; important prey species for certain snakes, birds, and mammals; significant relationship with humans; (e.g., white-footed or deer mouse and muskrat).

- ***Small Carnivorous/Omnivorous Mammals***
  Relatively abundant; relatively small home range; important consumers of aquatic and terrestrial biota; sensitive to PCB exposure; significant relationship with humans; (e.g., mink).

- ***Top Predators***
  At greatest risk for contaminants that bioaccumulate and biomagnify, including PCBs; significant relationship with humans; potentially species of concern; (e.g., red fox, great horned owl, peregrine falcon, bald eagle).

3.3 Identification of Endpoints

This section introduces, defines, and discusses appropriate assessment and measurement endpoints for evaluating potential ecological effects.

3.3.1 Assessment Endpoints

Assessment endpoints identify the ecological values to be protected (e.g., abundance and diversity of aquatic macroinvertebrates or fish). Assessment endpoints are directly related to ERA-related remedial action goals and objectives determined for the API/PC/KR. Appropriate assessment endpoints are developed by risk assessors and often consider guidance from relevant regulatory agencies. ERA-related remedial action goals and objectives for the API/PC/KR have been determined by MDEQ, and include: (1) the establishment and maintenance of a healthy and diverse aquatic ecosystem in and adjacent to the API/PC/KR, and (2) reductions in PCB concentrations in fish and wildlife such that human consumption restrictions can be lifted. Site-specific remedial action goals and objectives should include: (1) the removal from the environment and destruction of all PCB-contaminated soils, sediments and groundwater to a level that will achieve minimum water quality standards in the Kalamazoo River and Portage Creek (0.000026 ug/L for human health and 0.00012 ug/L for wildlife), and (2) remediation until residual levels in the environment are so low that healthy, safe-to-consume (no fish fillets greater than 2 ppm), self-reproducing, and ecologically diverse fish and wildlife populations can return to and survive in the Kalamazoo River basin. The Michigan Department of Environmental Quality, Wildlife Division suggests that a water, soil, and whole fish cleanup objectives be set a current minimum detectable levels of 0.3 ppm. These are to be achieved while avoiding or minimizing a loss of floodway/floodplain capacity, reductions in river channel lenght, or loss of wetland values. Assesssment endpoints are described as explicit expressions of the environmental variable(s) that are to be protected. The characteristics of the contaminants of concern, toxic mechanisms, and exposure pathways were used to select the following assessment endpoints:

- Preservation of the fish populations (e.g., smallmouth bass, white sucker, and carp) and communities utilizing the Kalamazoo River and Portage Creek system;

- Preservation of the survival, growth, and reproductive capacity of aquatic receptors (e.g., aquatic plants, benthic macroinvertebrates, fish, larval amphibians) utilizing the Kalamazoo River and Portage Creek system;

- Preservation of the survival, growth, and reproductive capacity of mammalian receptors (e.g., mouse, mink, muskrat, red fox) utilizing the Kalamazoo River and Portage Creek system; and,

- Preservation of the survival, growth, and reproductive capacity of avian receptors (e.g., bald eagle and great-horned owl) utilizing the Kalamazoo River and Portage Creek system.

It is assumed that the protection of the a forementioned sensitive aquatic and terrestrial receptors would be associated with the protection of other less sensitive organisms or receptors for which toxicity data are lacking such as reptiles, songbirds, etc.).

3.3.2 Measurement Endpoints

Assessment endpoints are often difficult to measure or evaluate directly. For example, we cannot predict with certainty the critical concentration of PCBs in surface water and sediment that allows survival and successful reproduction of smallmouth bass or salmonids in the Kalamazoo River. Such critical concentrations are site-specific and depend on innumerable factors, including the requirements of prey species consumed by gamefish, chemical interactions (i.e., synergistic, antagonistic, or additive), and the physical and chemical characteristics of the API/PC/KR (e.g., streambed particle size, sediment organic carbon content, dissolved organic carbon concentration in surface water, temperature, dissolved oxygen, streambank and in-stream cover, etc.).

Measurement endpoints are used in cases where assessment endpoints cannot be directly measured or evaluated. Measurement endpoints are quantitative expressions of observed or measured biological responses to stressors relevant to selected assessment endpoints. For example, macroinvertebrate abundance (an assessment endpoint) can be evaluated using aquatic toxicity data (measurement endpoints) derived from appropriate laboratory tests. As a specific example, concentrations of PCBs in API/PC/KR surface water can be compared to concentrations in laboratory test water that resulted in observed ecologically significant effects to sensitive and relevant test species (e.g., smallmouth bass or closely related species). For this ERA, ecologically significant effects are defined as those affecting survival, growth, or reproduction. Other ecologically significant impacts such as effects on metabolic health were not considered. The example described above expresses the relationship between a relevant measurement endpoint (chronic effects concentration of PCBs in surface water) that is directly related to the assessment endpoints of game fish abundance and reproduction. Measurement endpoints selected for this are based on information from appropriate aquatic ecology/toxicology studies, water quality studies, and terrestrial toxicological studies (e.g., data summarized in EPA 1980 and Eisler 1986) and on site-specific abiotic and biological data.

3.4 Site Conceptual Model

The site conceptual model (SCM) is the primary output of the Problem Formulation phase of the ERA, and is used to develop a series of null hypotheses for the API/PC/KR, primarily those regarding potential exposure scenarios and the relationship between selected assessment and measurement endpoints. The null hypotheses for the API/PC/KR are defined as follows:

- The levels of PCBs in water, sediment, and biota are not sufficient to adversely affect the structure or function of the fish populations in the Kalamazoo River and Portage Creek System.

- The levels of PCBs in water, sediment, and biota are not sufficient to adversely affect the survival, growth, and reproduction of plant and animal aquatic receptors utilizing the Kalamazoo River and Portage Creek system.

- The levels of PCBs in water, sediment, and biota are not sufficient to adversely affect the survival, growth, and reproduction of mammalian receptors utilizing the Kalamazoo River and Portage Creek system.

- The levels of PCBs in water, sediment, and biota are not sufficient to adversely affect the survival, growth, and reproduction of avian receptors utilizing the Kalamazoo River and Portage Creek system.

The conceptual model (**Figure 3-11**) presents the potential exposure pathways for the primary chemical stressors (PCBs) associated with past industrial activities in or near the API/PC/KR. These pathways indicate how the ecological resources can co-occur or come in contact with hazardous chemicals or materials such as PCB-contaminated sediments, and include contaminant sources, fate and transport processes, and exposure routes. Some of the pathways shown in **Figure 3-11** are considered to be relatively minor, and not all are fully evaluated in this ERA.

This ERA is focused primarily on population-level risks associated with PCB contamination in abiotic media and biota. Because of the potential for PCBs to accumulate in biological tissues and exert adverse effects in upper trophic level biota, this ERA specifically considers bioaccumulation, food chain effects, and adverse effects in upper trophic level organisms. Reproductive effects in upper trophic level organisms such as top predators commonly follow long-term PCB exposure. Since reproductive effects are often observed before other types of effects, protection against reproductive effects should ensure that other adverse effects will not occur. Therefore, reproductive endpoints for top predators are also considered critical to this ERA. Finally, it is assumed in this ERA that population-level effects are most important for most species and that the loss of a single individual is not critical to the population or community. The focus on population-level effects rather than on effects to individual organisms is modified in this ERA for threatened or endangered species. In this case, adverse effects or a loss of even one individual is considered important. Related to the conceptual model are the preliminarily identified remedial action objectives for the API/PC/KR presented in Section 3.3.1. **Table 3-3** summarizes the relationship between assessment endpoints, hypotheses, measurement endpoints, and receptors.

3.5 Uncertainty Associated with the Site Conceptual Model

Uncertainties in Problem Formulation can arise from several sources, most significantly from assumptions used to initially focus the ERA. This ERA is by regulatory direction focused on the primary chemical contaminants identified at this site--PCBs. It is recognized that other chemical stressors have been identified onsite, including some that can be highly toxic and are known to substantially bioaccumulate. It is also recognized that this focused ERA is specifically intended to address PCB contamination at this site.

The major uncertainties in the Problem Formulation phase of the ERA probably stem from the assumptions used to develop the site conceptual exposure model (SCEM). The SCEM developed for this ERA is based on a focused ERA in which only key exposure pathways and chemical stressors are fully evaluated. Therefore, uncertainties associated with other minor exposure pathways (e.g., inhalation) or chemical stressors other than PCBs will not affect the outcome of this focused ERA. All major exposure pathways and pathway components related to PCB contamination at this site have been included in the SCEM. No sources of uncertainty are identified at this stage of the ERA that will substantially affect the outcome of the ERA.

FIGURE 3-11
POTENTIAL EXPOSURE SCENARIOS
KALAMAZOO RIVER SUPERFUND SITE ECOLOGICAL RISK ASSESSMENT
CONCEPTUAL MODEL - PART 1

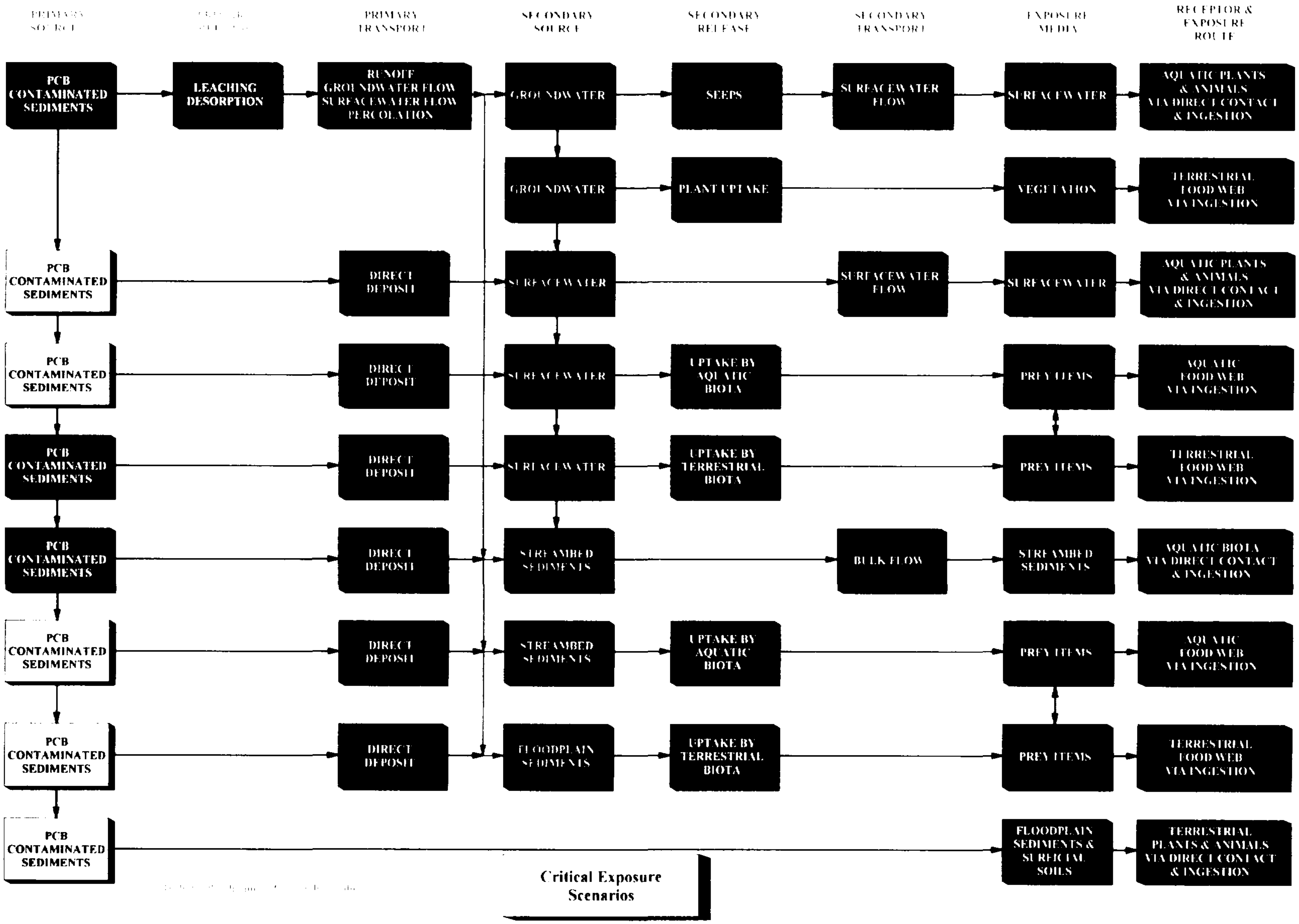


Table 3-3
Assessment and Measurement Endpoints and ERA Hypotheses

Assessment Endpoint	ERA Hypotheses	Measurement Endpoints	Representative Receptor / Group
Preservation of the fish populations (e.g., smallmouth bass, white sucker, and carp) and communities utilizing the Kalamazoo River and Portage Creek system	*The levels of PCBs in water, sediment, and biota are not sufficient to adversely affect the structure or function of the fish populations in the Kalamazoo River and Portage Creek System.*	*Toxicity data* - Surface water and sediment total PCB concentrations affecting the survival, growth, or reproduction of fish	Carp Smallmouth bass Sucker
Preservation of the survival, growth, and reproductive capacity of aquatic receptors (e.g., benthic macroinvertebrates, fish, larval amphibians) utilizing the Kalamazoo River and Portage Creek system	*The levels of PCBs in water, sediment, and biota are not sufficient to adversely affect the survival, growth, or reproduction of plant and animal aquatic receptors utilizing the Kalamazoo River and Portage Creek system.*	*Toxicity data* - Surface water and sediment total PCB concentrations affecting the survival, growth, or reproduction of aquatic plants, fish, aquatic invertebrates, or larval amphibians	Aquatic plants Benthic invertebrates Fish Larval amphibians
Preservation of the survival, growth, and reproductive capacity of mammalian receptors (e.g., mouse, mink, muskrat, red fox) utilizing the Kalamazoo River and Portage Creek system	*The levels of PCBs in water, sediment, soil,,and biota are not sufficient to adversely affect the survival, growth, or reproduction of mammalian receptors utilizing the Kalamazoo River and Portage Creek system.*	*Toxicity data and biota PCB concentrations* - Sediment, surface soil, and dietary item total PCB concentrations affecting the survival, growth, or reproduction of omnivorous and carnivorous mammals	Earthworm (dietary item) White-footed / deer mouse Muskrat Mink Red fox
Preservation of the survival, growth, and reproductive capacity of avian receptors (e.g., bald eagle and great-horned owl) utilizing the Kalamazoo River and Portage Creek system	*The levels of PCBs in water, sediment, and biota are not sufficient to adverselyl affect the survival, growth, or reproduction of avian receptors utilizing the Kalamazoo River and Portage Creek system.*	*Toxicity data and biota PCB concentrations* - Sediment, surface soil, and dietary item total PCB concentrations affecting the survival, growth, or reproduction of omnivorous and carnivorous birds	American robin Great horned owl Bald eagle

Section 4
Analysis Phase

This phase of the ERA analyzes exposure data (Exposure Assessment) and effects data (Effects Assessment) for the major stressors (PCBs) and representative receptors previously identified in Problem Formulation.

4.1 Ecological Exposure Assessment

Exposure Assessment evaluates and summarizes available exposure data, including exposure-related data on potential ecological receptors. The primary output of exposure assessment is an exposure profile that presents the magnitude (e.g., concentration) and distribution (e.g., surface water, sediment) of stressors to which ecological receptors may be exposed. For this ERA, the primary chemical stressors are PCBs because of the magnitude and extent of PCB contamination onsite. This focused ERA recognizes that other potential chemical stressors have been identified in the environment, but considers these other chemical stressors to be of much less ecological concern (i.e., much lower risk) than PCBs. Exposure profiles serve as input into the final stage of risk assessment, Risk Characterization.

4.1.1 Exposure Profiles - PCBs

Exposure Profiles describe the magnitude and distribution of stressors identified in the Problem Formulation phase. Exposure profiles for PCBs are summarized in Tables 4-1 and 4-2. Table 4-1 includes the site-wide range of total PCB concentrations and identifies the individual Aroclors for which abiotic media were sampled. Table 4-2 includes summary data on important chemical properties (i.e., environmental persistence, bioavailability, and bioconcentration potential) for PCBs. Additional stressors which may influence PCB contamination are presented at the end of this section. Non-chemical stressors are discussed in Section 4.1.2.

Recently collected data considered useable for risk assessment purposes are used to describe the magnitude and distribution of PCBs in the API/PC/KR environment. The majority of the abiotic (i.e., sediment, water, surface soil) data used in this ERA are from 1993 and 1994, when most of the biological sampling was conducted. Where data gaps have been identified, they have been addressed with data collected before 1993. In nearly all cases such data were taken from the Description of the Current Situation (BBL 1992). Data collected since 1994 are not included in the ERA because it is important to compare abiotic and biological data from the same time period to the extent possible. The extensive aquatic and terrestrial biological sampling conducted in 1993 serves as the basis for this ERA. Abiotic data collected in 1993 and 1994 are therefore considered most useful for comparison purposes. Such data are therefore used in this ERA except where important data gaps are identified. The relationships between biological data and abiotic data are established or estimated only for those ABSAs associated with 1993/1994 data. Where such data are lacking for a location or a abiotic media type, relationships are not established. These relationships include the derivation of soil/water partition factors, BCFs, and BSAFs.

Although no single concentration value can truly represent the variability of chemical concentrations measured in each medium of concern, the arithmetic mean value best represents the average concentration to which API/PC/KR receptors may be exposed. Where sufficient data have been collected, the arithmetic mean represents the average exposure concentration and the upper 95th confidence limit of the arithmetic mean (U95) is often used to represent a reasonable maximum exposure. Support for using U95 values is found in recent EPA guidance (1992b) for calculating values that are most representative of the higher end of actual chemical concentrations in environmental media to which human or ecological receptors may be exposed. This guidance states, however, that calculation of U95 values are appropriate only when sufficient data are available. In some cases, insufficient data have been collected from each individual sampling location to allow for complete confidence in U95 values. In cases where data are minimal, calculated U95 values sometimes exceed maximum detected concentrations.

Sufficient data for calculating U95 values have been collected for most *abiotic* and some biological media (e.g., fish). U95 values are therefore used to represent exposure concentrations in abiotic media and for those biological data associated with sufficient data. The latter category includes whole body fish tissue data. Arithmetic mean and maximum PCB concentrations in most media are also presentedin this section for comparison purposes. Arithmetic means include non-detect (ND) data using two accepted methods based on the source of the data. Means of abiotic data collected in 1994 are derived using a randomly selected number between zero and the laboratory reported detection limit to represent non-detects. In the few cases where older abiotic data are used, means are derived using the EPA-recommended method where half the detection limit is used to represent non-detects.

In cases where data are insufficient for deriving confident U95 values (e.g, mink, earthworms, mouse, muskrat), maximum detected values are used because they probably best represent reasonable maximum exposures. This is especially true where, because data are limited, the true maximum exposure concentrations are unlikely to have been measured. This approach is scientifically defensible considering data limitations, and in fact follows guidance provided by state and Federal regulatory agencies. For the most part, however, U95 values are considered representative of reasonable maximum exposure concentrations and are preferred where data quantity allow confidence in the derived values.

Finally, because this ERA is not based on a single line of evidence or single exposure point concentrations, the *distribution* of potential exposure concentrations associated with abiotic media is also considered important. For this reason , the arithmetic mean, U95, and maximum concentration of PCBs in abiotic media are also compared to relevant effects concentrations to additionally describe risks. These descriptions are presented graphically in Section 5 (Risk Characterization) for PCBs in surface water, streambed and floodplain sediment, and surface soil for each of the defined sampling areas. These graphical presentations (Figures 5-1 - 5-4) present total PCB concentrations for each abiotic media type overlaid with relevant media-specific effects concentrations, criteria, or thresholds.

Table 4-1 presents the site-wide (non-reference) and reference area ranges of total PCB concentrations detected in abiotic media. **Table 4-2** presents important chemical properties for the PCBs identified at the API/PC/KR. Each of these properties are discussed below.

Environmental Persistence
Environmental persistence indicates whether a chemical is likely to be long-lasting in the environment or, alternatively, be degraded by natural processes. Higher chlorinated PCBs, i.e. those with five or more chlorine atoms, are more persistent in the environment than those with three or less chlorine atoms (Eisler 1986). PCBs in sediments (including floodplain sediments) at the API/PC/KR are the higher chlorinated Aroclors.

Bioconcentration Potential
Bioconcentration potential indicates whether a chemical is likely to be retained in biological tissues after it is taken in by ingestion or other means. Retention of chemicals is not in itself an appropriate measurement endpoint unless it is associated with adverse ecological effects. Retention is, however, useful for verifying exposure and for evaluating bioavailability and the potential for food chain/food web effects. Bioconcentration factors (BCFs), derived under equilibrium conditions, are often used as screening-level data to evaluate bioconcentration potential. BCFs are based on the ratio of contaminant concentration in aquatic biota to contaminant concentration in water. Because BCFs are derived under equilibrium conditions and under relatively

long exposure durations, they consider both uptake and elimination (depuration) rates. Chemicals with BCFs greater than 300 generally indicate a potential to bioconcentrate

Table 4-1
Exposure Profile for PCBs
Sitewide Concentrations in Abiotic Media

Chemical	*Abiotic Media*	*Concentration Range Site-Wide*[1]	*(reference area*[2]*)*
Aroclor 1016 Aroclor 1221 Aroclor 1232 Aroclor 1242 Aroclor 1248 Aroclor 1254 Aroclor 1260	The following media types were analyzed for individual Aroclors and Total PCBs: Surface Water (SW) Streambed Sediment (SED) Floodplain Sediment (FP SED) Surface Soil (SS)	Concentration range for individual Aroclors not applicable - ERA is focused on distribution and magnitude of Total PCBs	
Total PCBs	Groundwater (GW, ug/L)	ND - 3	(NA)
	Surface Water (SW, ug/L)	ND - 0.23	(ND)
	Streambed Sediment (SED, mg/kg)	ND - 156	(NA)
	Floodplain Sediment (FP SED, mg/kg)	ND - 117	(NA)
	Surface Soil (SS, mg/kg)	0.065 - 34.5	(ND) - 0.39

1 Site-wide: API/PC/KR except upstream reference area (ABSA 1)
2 Reference Area: ABSA 1
ND= non-detect
NA= Data Not Available

(EPA, 1991). Chemicals with log BCFs above 3 (BCFs above 1,000) are considered to have significant potential to bioaccumulate (EPA, 1992b). For this ERA, available freshwater BCFs for invertebrates and fish that have potential to occur in the API/PC/KR, or those that are closely related to indigenous species, are used to evaluate bioconcentration potential. In addition, degree of chlorination for individual Aroclors is commonly used to estimate bioconcentration potential.

Bioavailability
For this ERA, bioavailable chemicals are defined as those that exist in a form that has the ability to cause adverse ecological effects or bioaccumulate. As stated previously, bioaccumulation may not in itself constitute a significant ecological effect, but provides important evidence of both exposure and potential for causing adverse effects to multiple trophic levels under certain conditions. For example, some lipophilic chemicals, such as PCBs, are taken up by biota and are stored in fatty tissues with no apparent ill effects.

Table 4-2
Exposure Profile for PCBs
Chemical Properties

PCBs	*Environmental Persistence*	*Bioconcentration Potential and Bioavailability*
General	All PCBs are environmentally persistent, but less chlorinated Aroclors (e.g., 1016, 1221) are more easily degraded by bacteria than more chlorinated Aroclors such as Aroclors 1254 and 1260 (Eisler, 1986).	Influenced by N-octanol/water partition coefficient (Kow) which relates to solubility, and by stearic factors relating to chlorine substitution patterns (Eisler, 1986). Bioaccumulation potential directly related to log Kow and stearic effects (Shaw and Connell 1982 in Eisler, 1986). Generally, less chlorinated Aroclors are taken up to a lower degree than highly chlorinated Aroclors. An exception is found with Aroclor 1254, which apparently is taken up to a greater degree than all other Aroclors studied, including Aroclor 1260 (Eisler, 1986). PCBs concentrate in liver, blood, and muscle in mammals. Generally, PCBs are lipophilic, and are most highly accumulated in fatty tissues. The pattern of Aroclor distribution in biological tissues, especially those of warm-blooded animals, only vaguely resemble the mixtures from which they originated (Hansen, et al., 1983 in Eisler, 1986). Most commonly, PCBs measured in tissues are identified as Aroclor 1260. PCB metabolism and bioaccumulation is species-specific, and similar exposures result in different bioaccumulation rates.
Aroclor 1221	Persistent	Low to Moderate Bioaccumulation Potential/Bioavailability[1]
Aroclor 1232	Persistent	Moderate Bioaccumulation Potential/Bioavailability[1] [1]Freshwater bioconcentration factor (BCF) for white sucker (*Catostomus commersoni*) equals 5,500 (Frederick, 1975 in EPA, 1980).
Aroclor 1016	Persistent	Moderate Bioaccumulation Potential/Bioavailability[1]
Aroclor 1242	Persistent	Moderate to High Bioaccumulation Potential/Bioavailability[1] Freshwater BCFs range from 36,000 (scud, *Gammarus pseudolimnaeus*, Nebeker and Pugilsi, 1974 in EPA, 1980) to 274,000 (fathead minnow, *Pimephales promelas*, Nebeker et al., 1974 in EPA, 1980).
Aroclor 1248	Persistent	High Bioaccumulation Potential/Bioavailability[1] Freshwater BCFs range from 52,000 (bluegill, *Lepomis macrochirus*, Stalling 1971 in EPA 1980) to 120,000 (fathead minnow, DeFoe et al. 1978 in EPA, 1980).
Aroclor 1254	Persistent	High Bioaccumulation Potential/Bioavailability[1] Freshwater BCFs range from 2,700 (phantom midge larvae, *Chaoborus punctipennis*, Mayer et al. 1977 in EPA, 1980) to 238,000 (fathead minnow, Nebeker et al., 1974 in EPA, 1980).

Table 4-2
Exposure Profile for PCBs
Chemical Properties

Aroclor 1260	Persistent	High Bioaccumulation Potential/ Bioavailability
		BCF for fathead minnow equals 270,000 (DeFoe, et al., 1978 in EPA, 1980)

Estimated from degree of chlorination and available freshwater BCFs

However, under stressful conditions, such as during winter when only poor quality foods are available, these fats are metabolized and the contaminants can then cause adverse effects.

Chemical properties (e.g., degree of chlorination) or environmental conditions (e.g., high levels of dissolved and particulate organic carbon) can affect the potential bioavailability and toxicity of many chemicals, including PCBs. The bioavailability and, therefore, toxicity of some PCBs in surface water can be influenced by the concentration of dissolved organic carbon. In addition, sediment organic carbon content, measured as total organic carbon (TOC), apparently affects bioavailability and toxicity of some PCBs. For some chemicals, chemical form and thus toxicity can change rather rapidly under changing environmental conditions (e.g., fluctuations in pH, temperature, or surface water flow). Seasonal conditions such as snowmelt and rainfall are likely to affect bioavailability of PCBs in the API/PC/KR. For the most part, however, PCB bioavailability (and potential toxicity) is expected to remain fairly stable because PCBs bind strongly to organic particulate matter. Once taken up by animals, PCBs are likely to be stored predominately in fatty tissues. PCB analyses of biological tissues generally measure Aroclor 1254 and (especially) Aroclor 1260. This finding is supported by studies that show biological conversion of one Aroclor to another after uptake. The chemical mixtures found in abiotic exposure media show little resemblance to Aroclors measured in biological tissues (Eisler, 1986). The finding that PCBs have been detected in the tissues of all sampled biota comprising multiple trophic levels at concentrations exceeding important thresholds supports the preliminary assumption that PCBs at this site are indeed bioavailable.

4.1.2 Exposure Profiles - Non-Chemical Stressors

Non-chemical stressors, such as disturbed habitats, are also important components of exposure profiles. Non-chemical stressors identified for the API/PC/KR include siltation of instream substrates, historical damming of Portage Creek and the Kalamazoo River, and disturbed riparian/terrestrial habitats adjacent to both the creek and the river. These physical stressors occur throughout the API/PC/KR to limited degrees, but impacts are expected to minimal when compared to the affects from PCBs. The potential effects of these non-chemical stressors are discussed in Effects Characterization (Section 4.2) of the ERA.

4.1.3 Exposure Scenarios

Exposure-related information for each of the representative groups of organisms previously identified as potential receptors for this ERA is described in this section These descriptions are based on likely exposure scenarios preliminarily identified in the SCM developed in the Problem Formulation phase of the ERA. These preliminary exposure scenarios are refined for the major representative receptor groups previously identified. The receptor groups represent those organisms identified in Section 3.2.2, and include those that are presently being exposed, have potential to be exposed under current conditions. Exposure scenarios, summarized in **Table 4-3,** are simplified descriptions of how potential receptors or representative receptor groups may come in contact with previously identified stressors.

As presented in **Table 4-3**, some organisms or representative groups of organisms can be exposed to contaminants by direct uptake (through or on roots of plants) or by ingestion of contaminated media and/or prey. Estimates of plant uptake are most appropriately based on site-specific soil-to-plant transfer factors and on ambient concentration of contaminants in surface soils. Such data are not, however, currently available for common plant species of the API/PC/KR. Daily intake rates for representative animals are most appropriately calculated using site-specific data (e.g., contaminant concentrations in food items and dietary composition). Site-specific soil-to-plant transfer factors and certain other critical input parameters for deriving site-specific daily intake rates for terrestrial animals are, however, unavailable for this ERA. Daily intake rates for terrestrial animals are, therefore, based on literature values for dietary intake and site-specific tissue data. Exposure scenarios for representative aquatic and terrestrial plants and animals are discussed below.

Exposure Scenarios

Although several potential exposure scenarios can be identified for ecological receptors, it is most appropriate to focus the assessment on critical exposure scenarios. This ERA is focused on the most critical exposure scenarios identified in the SCM (**Figure 3-11**). Critical exposure scenarios are discussed below.

Aquatic Exposure.

The primary PCB-related risks for aquatic organisms are likely to be from direct contact with and ingestion of contaminated surface water (including suspended sediments) in areas where surface water PCB concentrations are elevated. In addition, ingestion of bottom sediment and sediment pore (interstitial) water with elevated PCBs poses risks to benthic invertebrates, and to varying extents, other aquatic biota.

Finally, aquatic organisms that occupy upper trophic levels can be adversely affected by ingesting PCB-contaminated prey. The relative contribution from each exposure source (surface water, sediment, interstitial water, prey) to overall aquatic exposure to PCBs can not, however, be reliably determined for most aquatic organisms because data describing the variability in factors that can affect total exposure are lacking. These factors can include intraspecific and interspecific differences in life stage, season, diet, ingestion rate, specific habitat, etc. This assessment evaluates potential risks posed to aquatic biota primarily by comparing ambient PCB concentrations in surface water and streambed sediment to media-specific criteria, such as chronic ambient water quality criteria (AWQC) and critical effects concentrations (e.g., lowest observed adverse effects concentrations or LOAECs) for appropriate species.

Terrestrial Exposure.
Because PCBs tend to bioconcentrate to a high degree and biomagnify, ingestion of contaminated surface water and surface soil by terrestrial animals is expected to be less significant than ingestion of contaminated food. The uptake of chemical contaminants by terrestrial plants can also be important if the contaminants of concern are easily taken up, phytotoxic, or can cause food chain effects to herbivorous consumers. The importance of the food-ingestion pathway and uptake by terrestrial plants depends, however, on the types and abundance of plant and animal receptors as well as on the types and concentrations of chemical contaminants present. Terrestrial/riparian wildlife are common along the API/PC/KR, even though riparian and terrestrial habitats have been visibly degraded in some areas. Significant potential, therefore, exists for terrestrial and riparian species to be exposed to PCB contamination.

Table 4-3
Exposure Information for Representative Ecological Receptors

Representative Receptor Group	*Primary Stressor*	*Primary Potential Exposure Routes /Processes*
Aquatic Plants (e.g., floating and rooted macrophytes and algae)	SW PCBs	SW Contact and Uptake
	SED PCBs	SED/IWContact and IW Uptake
Aquatic Macroinvertebrates (e.g., mayfly larvae)	SW PCBs	SW Contact and Ingestion, Ingestion of PCB-contaminated Prey
	SED PCBs	SED/IW Contact and Ingestion, Ingestion of PCB-contaminated Prey

Table 4-3
Exposure Information for Representative Ecological Receptors

Freshwater Game Fish (e.g., smallmouth bass)	SW PCBs	SW Contact and Ingestion, Ingestion of PCB-contaminated Prey
	SED PCBs	SED/IW Contact and Ingestion, Ingestion of PCB-contaminated Prey
Freshwater Forage Fish (e.g., white sucker)	SW PCBs	SW Contact and Ingestion, Ingestion of PCB-contaminated Prey
	SED PCBs	SED/IW Contact and Ingestion, Ingestion of PCB-contaminated Prey
Freshwater Rough Fish (e.g., common carp)	SW PCBs	SW Contact and Ingestion, Ingestion of PCB-contaminated Prey
	SED PCBs	SED/IW Contact and Ingestion, Ingestion of PCB-contaminated Prey
Terrestrial Invertebrates (e.g., earthworms)	SS/FP SED PCBs	SS/FP SED Contact and Ingestion
Small Burrowing Terrestrial and Semi-aquatic Mammals (e.g., deer and white-footed mouse, muskrat)	SED/FP SED/SS PCBs	SED/FP SED/SS Contact and Ingestion, Ingestion of PCB-contaminated Vegetation/Prey
Small Omnivorous/ Carnivorous Mammals (e.g., mink)	SW/SED/FP SED PCBs	Ingestion of PCB-contaminated Aquatic and Terrestrial Prey
Top Predators (e.g., red fox, great horned owl, bald eagle)	SW/SED/FP SED/SS PCBs	Ingestion of PCB-contaminated aquatic and terrestrial prey

SW = Surface Water FP SED = Floodplain Sediment IW = Interstitial Water
SED = Instream Sediment SS = Surface Soil

Terrestrial/riparian plant communities along the API/PC/KR can be affected by past industrial activities and other human-induced stresses. In some areas containing PCB residual material (e.g. A-Site) the effects are sufficiently limiting to preclude the existence of vegetation, and in other areas existing plant communities are dominated by "weedy" type forbs and shrubs. The causes of observed stress on certain plant communities has not been determined, but may be the result of physical (e.g., habitat alteration) or chemical (contamination/toxicity) stress.

Most herbivorous wildlife species are unlikely to frequent the few barren areas; however, those areas dominated by weedy forbs may be an attraction to certain receptors within the API/PC/KR. Several terrestrial/riparian vertebrate species common in western Michigan that require suitable vegetative cover and other specific habitat requirements (e.g., muskrat and white-footed mouse) are commonly observed within all or portions of the API/PC/KR. Although suitable habitat for mink is common in the API/PC/KR area, populations appear depressed based on recent MDEQ trapping results.

Because vegetation is only rarely absent or visibly stressed within the API/PC/KR, and because herbivorous wildlife are common, plant consumers can be exposed to site-related contaminants (e.g., PCBs) under present conditions. Similarly, most predators or consumers of herbivorous species can also be exposed to site-related contaminants because adequate cover and prey are generally available.

Although a large variety of commonly observed terrestrial animal species including resident and migratory birds have been reported onsite, certain other local types of animals species that are not easily observed or often reported probably also occur regularly or permanently within the API/PC/KR. These include macroinvertebrates (e.g., insects, spiders, centipedes, millipedes), amphibians (e.g., true toads, true frogs, treefrogs, salamanders, newts), reptiles (e.g., lizards, snakes, turtles), and mammals (e.g., shrews, raccoons, voles, skunks, weasels, etc.) and are summarized in the tables in **Appendix A**. Although for the most part data are lacking, risks to these organisms could occur as a result of direct contact with or ingestion of contaminants via surface water, sediment, soil, and food items. For many terrestrial ecological receptors exposed to PCBs, the most important pathway involves ingestion of PCB-contaminated prey. Finally, PCB exposures are likely to be limited in areas with insufficient cover and prey because such areas are probably avoided by most terrestrial species.

Although portions of the API/PC/KR riparian habitat have been reduced by commercial, industrial and residential development, many resident species have apparently adapted to the encroachment of humans and these species can therefore be found in close proximity of the landfills and abandoned industrial facilities along the Kalamazoo River and Portage Creek.

Exposures via Food Chain Transfer.
PCBs detected onsite differ in their persistence in the environment and the severity of adverse effects. Some of the PCBs commonly identified onsite are known to bioaccumulate as a result of ingestion of contaminated surface water, sediment, soil, vegetation, or prey. Bioconcentration factors (BCFs) or bioaccumulation factors (BAFs) are often used as screening-level data to evaluate bioaccumulation potential. As stated previously, chemicals with BCFs less than 300 are considered to have low bioaccumulation potential, while those with BCF between 300 and 1,000 have moderate potential to bioaccumulate. Chemicals with BCFs greater than 1,000 are of most concern with regard to potential bioaccumulation. **Table 4-2** lists literature-based freshwater BCFs for the PCBs detected onsite. A qualitative presentation of data associated with the ingestion pathway for PCBs and representative receptor groups is presented in Table 4-4.

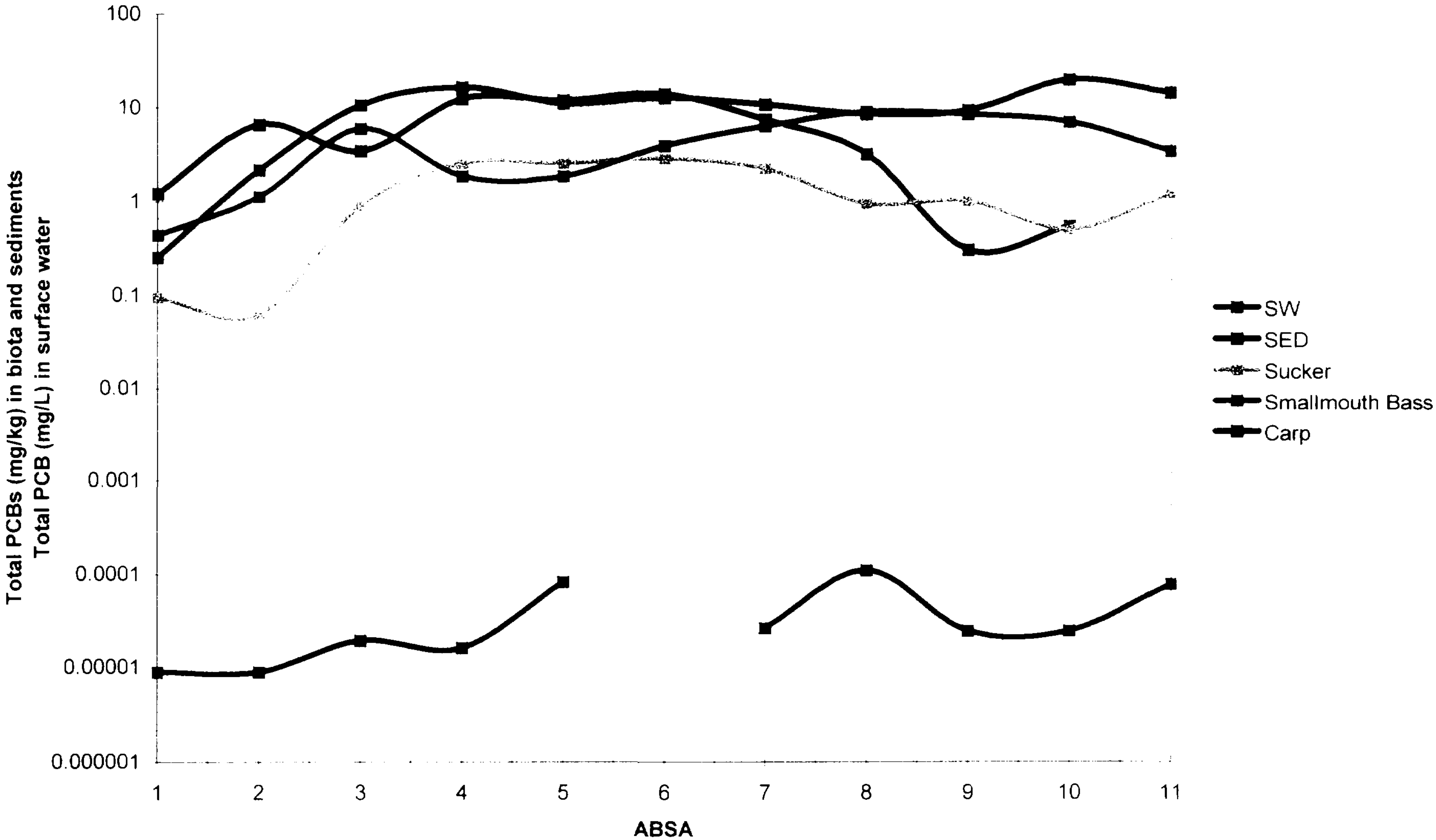
4.1.4 Exposure Analysis

Information on distributions of stressors and receptors are combined and summarized in this section, and potential for exposure is discussed. For PCBs, such discussions consider important chemical properties summarized in **Table 4-2** (i.e., environmental persistence, bioavailability, and bioconcentration potential). For identified receptors or representative groups of receptors, estimates of potential exposure consider the important ecological parameters that can potentiate or modify exposure, such as habitat use and foraging behavior. Exposure-related information for key organisms or representative receptors is summarized in **Appendix B**.

Samples of several representative organisms, including some of those discussed above, were collected and analyzed for whole body PCB analyses. The U95 (fish) and maximum (terrestrial biota) whole body PCB concentration for each of these organisms or groups of organisms is used to evaluate PCB exposure in representative biota, and support food chain modeling. The concentrations and ABSA-wide distributions of PCBs in sampled biota and abiotic media are presented in Table 4-5. These data are presented on an area-by-area basis. This presentation is based on previously defined spatial units for sampling aquatic biota (ABSAs) and terrestrial biota (TBSAs) (**Figures 3-1 to 3-10**). As discussed previously, boundaries of ABSAs are defined so that all areas of the API/PC/KR are associated with an ABSA. This expansion of ABSAs beyond sampled areas is not intended to suggest that the abiotic (i.e., sediment, soil, and water) samples collected are representative of non-sampled areas within the ABSA. The variability of such samples precludes having much confidence in such assumptions. Instead, the ABSAs are expanded in consideration of mobile receptors such as fish and mink. The PCB concentrations of mobile receptors collected within an ABSA are assumed to be (1) representative of concentrations in mobile biota found in the expanded ABSA, and (2) the result of exposures from within the entire ABSA.

Also, **Figure 4-1** graphically presents the relationships between PCBs in surface water, sediment, and whole body fish collected onsite, on a ABSA-specific basis. This figure reveals that PCB concentrations in fish and abiotic media are generally related but the relationship is not linear. This finding is not unexpected since fish receive PCBs from multiple sources and via several exposure pathways. PCB concentrations in fish tissue are therefore not expected to be directly and completely correlated to PCB concentrations in surface water, sediment, or prey.

Figure 4-1
U95 Total PCB Concentrations
in Fish, SW, and SED



More importantly, it is expected and confirmed that elevated fish tissue PCB concentrations are associated with elevated PCB concentrations in abiotic media. In addition, low fish tissue PCB concentrations are associated with low PCB concentrations in abiotic media.

4.1.5 Food Web/Food Chain Modeling

The PCB Food Web Model (**Figure 4-2**), described below and presented in **Appendix C**, is one component of the ERA. These key species were selected because they are common or potential inhabitants of the API/PC/KR corridor and most likely obtain their food from the river and/or associated terrestrial habitats. USEPA Region V Biological Technical Advisory Group (BTAG) has approved these key species for this ERA. Section 5.1.4 provides a discussion on the estimated average potential daily dosage (APDD) and threshold effects values for "key" species. This is a simplified model utilizing measured and estimated input parameters and established mathematical relationships between input parameters. Models such as these are used to estimate the average potential dietary exposure for upper trophic level organisms from ingestion of contaminated prey. For this ERA, the risks posed to lower trophic level organisms and all fully aquatic organisms are assessed by comparing exposure point concentrations in exposure media to concentrations that can cause ecologically significant effects. For this ERA, ecologically significant effects are defined as those adversely affecting survival, growth, or reproduction. Survival or mortality can be determined in acute toxicity tests (i.e., tests of short duration and generally high exposure concentrations) or chronic toxicity tests (i.e., tests of long duration and comparatively lower exposure concentrations). Growth and reproductive effects are usually measured by chronic testing. PCBs are not acutely toxic to many species, yet long-term exposures can have adverse effects on individuals, populations, and communities. The presence of detectable PCB concentrations in biological tissues is not in itself considered ecologically significant unless such concentrations can be correlated to adverse effects. For example, common snapping turtles (*Chelydra serpentina*) are known to accumulate and retain substantial amounts of PCBs in fatty tissues with no observed ill effects (Olafsson, et al., 1983 in Eisler, 1986). Consumers of snapping turtles, however, may be at significant risk if dietary intake is of sufficient quantity, frequency, and duration to e exposure to PCB concentrations similar to those measured at the API/PC/KR.

As previously stated, it is most appropriate to focus the ERA on critical exposure scenarios. This ERA, and specifically the food web model, is focused on the most critical exposure scenarios for ecological receptors. For terrestrial species, and for nearly all identified carnivores, the potential exposure from ingestion of PCB-contaminated surface water is considered insignificant relative to the potential risks from ingestion of PCB-contaminated prey.

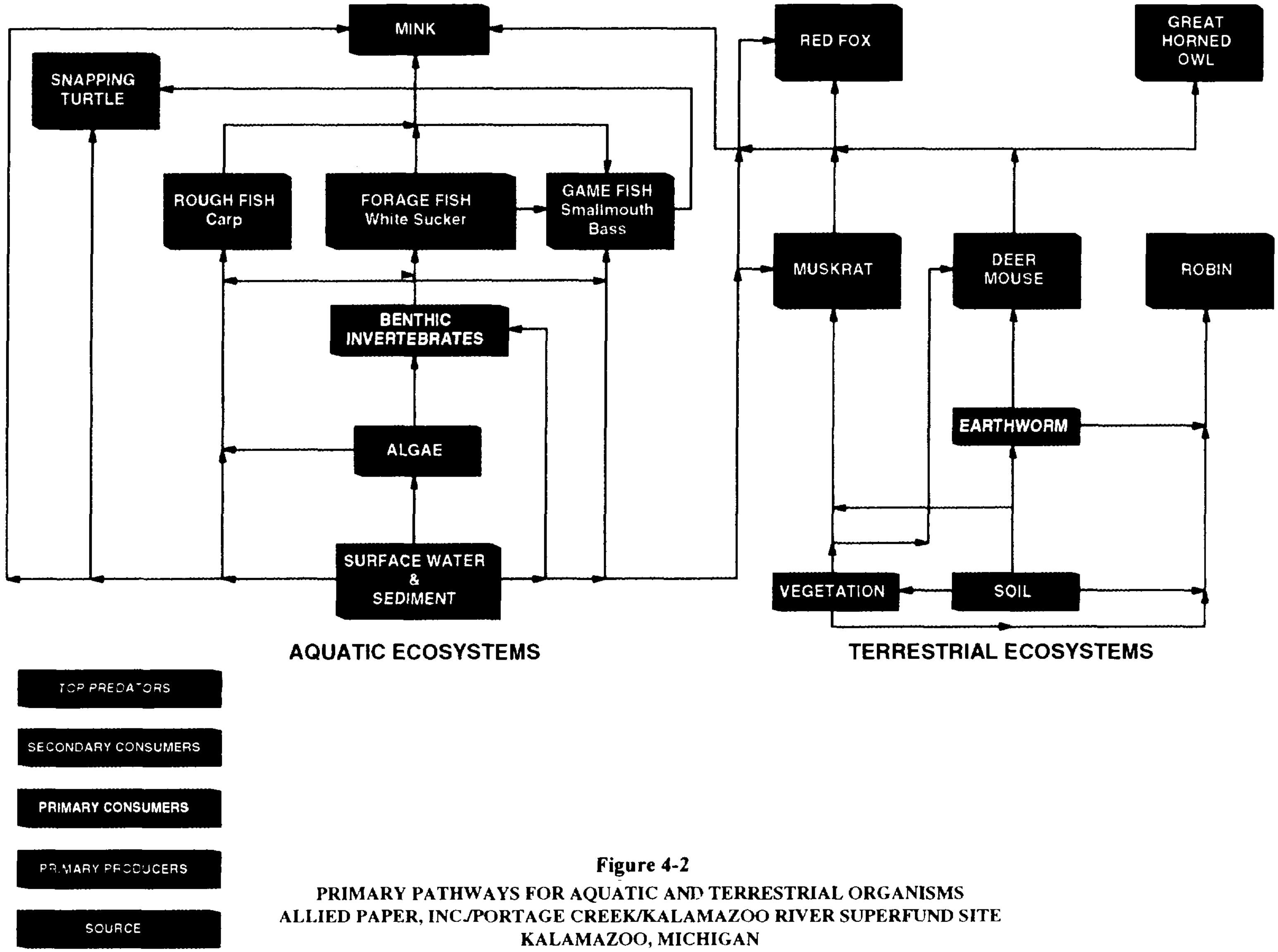


Figure 4-2
PRIMARY PATHWAYS FOR AQUATIC AND TERRESTRIAL ORGANISMS
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
KALAMAZOO, MICHIGAN

This assumption is based on relatively low surface water PCB concentrations and total potential PCB intake compared to prey concentrations and total potential intake via ingestion of contaminated prey. The potential risks to carnivores and all terrestrial species from the ingestion of PCB-contaminated surface water is, therefore, not included in this assessment.

The primary PCB-related risks for aquatic organisms, especially those occupying lower trophic levels, are likely to be from direct contact with and ingestion of contaminated surface water, sediment, and pore or interstitial water. Certain aquatic organisms such as predatory gamefish can also be significantly exposed to PCBs through ingestion of contaminated prey. The relative contribution to overall PCB exposure from each exposure pathway and exposure source (e.g., water, sediment, prey) can not, however, be reliably determined for most aquatic organisms because of the variability in factors that can affect total exposure. These factors can include intraspecific and interspecific differences in life stage, season, diet, ingestion rate, specific habitat, etc. This assessment evaluates potential risks posed to aquatic biota primarily by comparing ambient PCB concentrations in surface water and sediment to media-specific and, where appropriate, site-specific criteria, standards, or critical effects concentrations (e.g., lowest observed adverse effects concentrations or LOAECs).

A primary output of the PCB Food Web Model is an estimation of the average potential daily dose (APDD mg PCB/kg body weight-day) from ingestion of PCB-contaminated prey for upper trophic level organisms. This estimation is based on the following formula from EPA (1993):

$$ADD_{pot} = \sum_{K=1}^{n} (C_k * FR_k * NIR_k)$$

Where:

ADD_{pot}	= *Potential Average Daily Dose (mg PCB/kg BW-day)*
C_k	= *Average PCB Concentration in the k^{th} food type (mg/kg)*
Fr_k	= *Dietary Fraction of intake of the k^{th} food type (range 0 - 1.0)*
NIR_k	= *Normalized Ingestion Rate of the k^{th} food type (wet weight of prey ingested per day, g/d)*
n	= *number of contaminated food types*

Normalized ingestion rate is the ingestion rate normalized for body weight:

$$NIR_k = IR_k / BW$$

Table 4-4
Potential Exposure Via Contaminant Ingestion Pathway for Representative Aquatic and Terrestrial Organisms

Representative Receptor Group	***Primary PCB Exposure Media***	***Discussion of Uptake/Ingestion Pathway***
Aquatic Plants (e.g., floating and rooted macrophytes and algae)	SW SED	Hydrophobic PCBs in the water column are physically adsorbed on particulate matter, including algal cells (Eisler, 1986). In addition, PCBs can be transferred from aqueous solution into algal lipids. These PCBs then can cause direct toxic effects to algae by inhibiting photosynthesis and motility. Finally, PCBs accumulated by algae are readily introduced into aquatic food chains (Rohrer, et al., 1982 in Eisler, 1986).
Aquatic Macroinvertebrates (e.g., mayfly larvae)	SW SED	PCBs can be taken up by aquatic macroinvertebrates via ingestion of surface water, sediment, sediment pore water, and PCB-contaminated prey such as algae. Uptaken PCBs can cause direct toxic effects in macroinvertebrates, and can also be passed on to upper trophic level organisms through ingestion of PCB-contaminated macroinvertebrates. In addition, certain types of macroinvertebrates, such as mysid crustaceans in Lake Michigan, have a low assimilation efficiency for PCBs and a high efficiency for fecal excretion of ingested PCBs (Evans, et al., 1982 in Eisler 1986). PCB uptake from sediment by chironomids (midge larvae) can be correlated to sediment PCB concentration (Larsson, 1984 in Eisler, 1986). PCBs can be transported from aquatic to terrestrial environments via aquatic midge larvae · terrestrial midge adults (Larsson, 1984 in Eisler, 1986). Terrestrial consumers of adult midges can therefore be indirectly exposed to sediment-source PCBs.
Freshwater Game Fish (e.g., smallmouth bass)	SW SED PREY	More persistent and highly chlorinated PCBs can be found in trace amounts in fish from almost every major river in the United States (Schmitt, et al., 1985 in Eisler, 1986). PCB-contaminated sediments and atmospheric deposition are the most important sources of PCBs in fish (Eisler, 1986). Several studies reveal downward trends in PCB concentrations in whole body fish from throughout the U.S., especially for less chlorinated PCBs such as Aroclor 1242 (Eisler, 1986). Total PCBs in fish measure environmental PCB contamination more reliably than do measurements for specific commercial mixtures such as Aroclor PCBs (Schmitt, et al., 1985 in Eisler, 1986). Diet is major route of PCB uptake in most fish, but water can be a major source of PCB uptake in certain species under certain conditions (Greig, et al., 1983 in Eisler, 1986). Although lipophilic, PCBs can also be deposited in gonads, eggs, muscle, and skin to varying degrees, depending on fish species (Eisler, 1986).
Freshwater Forage Fish (e.g., white sucker)	SW SED	As above, but ingestion of prey less important because of omnivorous diet. Uptake of PCBs expected to be lower than for piscivorous gamefish or bottom dwelling rough fish.
Freshwater Rough Fish (e.g., common carp)	SW SED	As above, but ingestion of prey less important because of mostly herbivorous diet. Incidental ingestion of sediment may be important exposure route for bottom dwelling rough fish such as common carp. Direct contact with and ingestion of PCB-contaminated pore (interstitial) water may greatly increase exposure potential for benthic rough fish such as common carp.
Terrestrial Invertebrates (e.g., earthworm)	SS FP SED	Little data exist on PCB transfer from surface soil and floodplain sediments to earthworms. Earthworms that have depurated ingested surface soil (i.e., "empty" earthworms) are expected to have lower whole body PCB concentrations than surface soils from which they were collected because of rapid movement of soil through earthworms.

Table 4-4
Potential Exposure Via Contaminant Ingestion Pathway for Representative Aquatic and Terrestrial Organisms

Representative Receptor Group	*Primary PCB Exposure Media*	*Discussion of Uptake/Ingestion Pathway*
Small Burrowing Terrestrial and Semi-Aquatic Mammals (e.g., deer and white-footed mouse, muskrat)	SED FP SED PREY	Terrestrial burrowing rodents such as the white-footed deer mouse, are likely to ingest PCBs primarily through ingestion of invertebrate prey and plants. Vegetation portion of the diet is expected to contribute only small amounts of PCBs compared to contribution from animal prey. Semi-aquatic burrowing mammals like muskrats that are primarily herbivorous are most likely to take in PCBs through incidental ingestion of PCB-contaminated streambed and floodplain sediments. Omnivorous and herbivorous small mammals are expected to have lower PCB exposures than carnivorous species, especially those that consume substantial amounts of aquatic prey (e.g., mink).
Small Omnivorous/ Carnivorous Mammals (e.g., mink)	PREY	Mink are especially sensitive to PCBs, and their diet includes organisms that are most likely to be highly contaminated with PCBs (rough fish, benthic invertebrates such as crayfish, etc.). Several studies suggest that more highly chlorinated PCBs are eliminated more slowly than lower chlorinated PCBs in semi-aquatic carnivorous mammals studied (Eisler, 1986).
Top Predators (e.g., red fox, great horned owl, bald eagle)	PREY	PCB contamination most important to top predators (upper level carnivores) compared to lower trophic level organisms (Shaw and Connell, 1982; Malins, et al., 1980 in Eisler, 1986). Consumers of PCB-contaminated fish are likely to be at most risk because elevated PCB concentrations are expected in fish and other aquatic biota. Exposure through ingestion of prey must consider exposure frequency and duration as well as diet, and foraging range of top predators is critical to this evaluation.

TABLE 4-5
Concentration and Distribution of Total PCBs in Sampled Biota and Abiotic Media

MEDIA (ppm)		TBSA 11 ABSA 1	ABSA 2	Portage Creek	ABSA 3	TBSA 10 ABSA 4	ABSA 5	ABSA 6	ABSA 7	TBSA 3, 5 ABSA 8	ABSA 9	TBSA 1 ABSA 10	ABSA 11
Smallmouth Bass [1]	(max)	0.62	1.8		15	2.3	7.9	8.3	7.6	11	12	8.4	5.0
	(mean)	0.35	0.83		3.6	1.4	4.6	2.5	5.1	6.9	6.5	5.6	2.6
	(U95)	0.43	1.1		5.8	1.8	1.8	3.8	6.1	8.7	8.2	6.8	3.3
Sucker [1]	(max)	0.14	0.8	2.4	1.0	2.9	3.1	4.6	2.8	1.1	1.7	0.92	1.6
	(mean)	0.074	0.054	1.4	0.081	2.2	2.2	2.2	2.1	0.78	0.81	0.35	1.1
	(U95)	0.096	0.063	1.9	0.90	2.5	2.5	2.8	2.3	0.93	1.0	0.49	1.2
Carp [1]	(max)	0.41	4.2	10.8*	15	21	14	20	25	14	21	36	32
	(mean)	0.20	1.4		8.1	12.8	8.8	8.5	6.3	6.5	5.6	13.2	8.9
	(U95)	0.25	2.1		10.4	16.1	10.7	12.3	10.5	8.3	9.0	19.1	13.9
Earthworm [1]	(max)	ND				0.66				3.2 (TBSA 3) 2.2 (TBSA 5)		0.025	
White-footed/ Deer Mouse [1]	(max)	ND				0.28				0.45 (TBSA 3) 0.38 (TBSA 5)		0.35	
Muskrat** [2]	(max)	ND						2.0		8.4*** (TBSA 5)		3.1	
Mink** [2]	(max)	6.4						7.6		15.5 (TBSA 5)		12.0	
Surface Water [3]	(max)	0.0000075	0.0000075	0.000230	0.000048	0.000035	0.000091	no data	0.000071	0.000120	0.000052	0.000028	0.00012
	(mean)	0.0000063	0.0000063	0.000058	0.000015	0.000013	0.000062	no data	0.000022	0.000075	0.000020	0.000018	0.000059
	(U95)	0.0000088 (ABSA 1-2)	0.0000088 (ABSA 1-2)	0.000059	0.000019	0.000016	0.000081	no data	0.000026	0.000108	0.000024	0.000024	0.000077
Streambed SED[3]	(max)	no data	2.4	120	86	44	100	94	156	91	7.2	0.73	1.4
	(mean)	no data	0.91	31.3	2.3	1.6	6.1	5.4	4.9	2.9	2.4	0.20	0.27
	(U95)	no data	1.2	47.1	6.5	3.4	12.2	11.8	13.6	7.3	3.1	0.30	0.53
FP SED [4]	(max)	no data	no data	no data	no data	no data	85	no data	117	81	no data	0.20	no data
	(mean)	no data	no data	no data	no data	no data	12.7	no data	13.9	12.2	no data	0.20	no data
	(U95)	no data	no data	no data	no data	no data	18.9	no data	21.1	15.9	no data	NA	no data
										TBSA 3 / TBSA 5			
Surface Soil[5]	(max)	0.39	no data	no data	no data	10.2	no data	no data	no data	32.6 / 34.5	no data	0.23	no data
	(mean)	0.21	no data	no data	no data	6.5	no data	no data	no data	24.5 / 25.1	no data	0.17	no data
	(U95)	0.33	no data	no data	no data	8.9	no data	no data	no data	28.3 / 30.2	no data	0.23	no data

TABLE 4-5
Concentration and Distribution of Total PCBs in Sampled Biota and Abiotic Media

	TBSA 11 ABSA 1	ABSA 2	Portage Creek	ABSA 3	TBSA 10 ABSA 4	ABSA 5	ABSA 6	ABSA 7	TBSA 3, 5 ABSA 8	ABSA 9	ABSA 10	ABSA 11
Mean Streambed SED/SW Partition Factor (Kd)[6]				342,105	212,500			523,077		129,167		
Mean Sitewide Kd	301,712											
Mean FP SED TOC (%)					8.99	8.34		8.25	7.29			
Mean Sitewide % TOC	8.2											

ND: PCBs Not Detected
no data: no recent data available for location or media type
NA: not applicable

* estimated from filet and remaining carcass PCB concentrations (0.90 * PCB conc of remaining carcass: 0.90*12 mg/kg)
** estimated whole body conc from ((PCB carcass*WT carcass)+(PCB liver*WT liver))/WT whole body
*** estimated from carcass value without liver--no data for liver PCB conc from this sample

Footnotes

1) Blasland, Bouck & Lee, Biota Investigation, July 1994
2) MDNR, June 1994
3) Blasland, Bouck & Lee TM16, March 1995 (SW PC, ABSA 3,4,7,9,10) and TM10, April 1994 (SED ABSA 3,4,5,6,7,8,9)
   Blasland, Bouck & Lee Description of the Current Situation, May 1992 (SED PC, ABSA 2, 10, 11 and SW ABSA 1,2,5,8, 11)
   Surface Water Data for ABSAs 1 and 2 from samples taken at location near border of ABSA 1 and 2
   Surface Water Data for ABSAs 1 and 2 estimated from two samples, less than detection limit, using half the detection limit
4) Blasland, Bouck & Lee, Former Impoundment Sediment and Geochronologic Dating Investigation, 1994 (all ABSAs except 10)
   Blasland, Bouck & Lee Description of the Current Situation, 1992 (ABSA 10, single sample)
5) Blasland, Bouck & Lee, Results of Phase I TBSA Soil Sampling, February 1994
6) Kd calculated only for ABSAs where reasonably synoptic (1993/1994) SED data were collected

Where: IR_k is the ingestion rate (g/d) of the predator and BW is the body weight (g) of the predator.

The site foraging factor or SFF is commonly added to the above equation (multiplied in the numerator) to account for the fact that some animals forage over a wid range, and ingestion of contaminated prey may therefore be adjusted by the portion of the time foraging takes place in contaminated areas. This adjustment is most appropriate where predators with large foraging ranges are evaluated at small sites.

SFF = Site Foraging Factor (site area, hectares/home or foraging range, hectares) (range = 0 - 1.0)

This ERA does not adjust the SFF and retains the SFF at 1.0, assuming that the foraging range is less than or equal to the site area. This assumption appears conservative or overly protective until one considers that nearly the entire site provides suitable habitat and food for most predators. There is no reason to believe, or evidence, that predators such as mink will leave the site and obtain food beyond site boundaries. The bald eagles nests along the Kalamazoo River and will obtain most of its food from the Kalamazoo River corridor. This is critical, because if a breeding pair are capable of producing fledgings, they will most likey be fed contaminated prey from the Kalamazoo River corridor. Section 5 discusses some additional evidence that supports this preliminary assumption.

Each of these input parameters, in addition to other parameters used to support the ERA (e.g., bioconcentration factors), are discussed below. Finally, for readability, the potential average daily dose (ADD_{pot}) is referred to in subsequent sections of the ERA as the APDD or average potental daily dose.

Representative Species

For assessing potential risks to ecological receptors, certain local species are selected to represent important trophic levels in aquatic and terrestrial food chains for this site. Important trophic levels for each identified food chain include primary producers (plants), primary consumers (herbivores), secondary consumers (carnivores), and top predators (carnivores at the top of a food chain). Some organisms can occupy more than one trophic position in a food web. For example, raccoons consume both plants and animals and, in some food webs, can also be considered top predators. For this assessment, forage and rough fish include both herbivorous and carnivorous species, and detritivores are included with herbivores and omnivores.

Primary Trophic Levels and Categories of Representative Organisms

Primary Producers. General categories of organisms identified as primary producers include:

- Algae

- Aquatic macrophytes
- Terrestrial macrophytes

Primary Consumers. General categories of organisms identified as being predominantly herbivorous, omnivorous, or detritivorous, include:

- Aquatic invertebrates (benthic and water column)
- Forage fish
- Rough fish
- Terrestrial invertebrates
- Small terrestrial omnivorous rodents
- Omnivorous perching or songbirds
- Semi-aquatic herbivorous mammals

Secondary Consumers. General categories of organisms identified as being predominantly carnivorous include:

- Gamefish
- Small terrestrial/semi-aquatic carnivorous mammals
- Birds of prey
- Large terrestrial carnivorous mammals

Top Predators. Secondary consumers or carnivores specifically identified as top predators for this assessment, include red fox, great horned owl, bald eagle, and mink.

Local species are selected to represent general categories of organisms and important trophic levels in identified food chains. Several of these species or categories of organisms have been sampled to determine whole body PCB concentrations. Whole body (where applicable) PCB concentrations are estimated for other non-sampled species or categories of organisms. These estimates are based on species-specific bioconcentration or bioaccumulation factors (BCFs or BAFs) as much as possible, and on measured PCB concentrations in exposure media. For example, the PCB concentration in algae (mg/kg) is estimated by multiplying the measured surface water PCB concentration (mg/L) by an appropriately derived BCF for freshwater algae.

PCB concentrations in whole body or specific tissue are *measured* in several selected species, as summarized in **Table 4-5**. These species, and the associated trophic category, include:

- White sucker (*Catostomus commersoni*) or equivalent - forage fish

- Common carp (*Cyprinus carpio*) - rough fish

- Smallmouth bass (*Micropterus dolomieui*) - game fish
- Earthworm (*Lumbricus terrestris*) or equivalent - terrestrial invertebrate
- Deer mouse or white-footed mouse (*Peromyscus maniculatus* or *P. leucopus*) - small omnivorous terrestrial mammal
- Muskrat (*Ondatra zibethica*) - semi-aquatic herbivorous mammal
- Mink (*Mustela vison*) - small terrestrial carnivorous mammal

PCB concentrations are *estimated* for:

- Algae - Based on bioconcentration of PCBs in diatoms
- Aquatic and terrestrial macrophytes - Based on bioaccumulation of PCBs in terrestrial plants
- Aquatic invertebrates (benthic) - Based on bioconcentration of PCBs in scuds (*Gammarus*) and midge (*Chaoborus*) larvae determined in laboratory experiments
- Aquatic invertebrates (water column) - Based on bioconcentration of PCBs in cladocerans (*Daphnia*) and mosquito larvae (*Culex*)
- American robin (*Turdus migratorius*) - Based on estimated soil-to-plant transfer factors for terrestrial macrophytes, measured BAFs for earthworms, and BAFs for birds.

PCB tissue concentrations are neither measured nor estimated for the three remaining representative top predator species: great horned owl (*Bubo virginianus*), red fox (*Vulpes fulva*), and bald eagle (*Haliaeetus leucocephalus*). This is not considered a critical data gap for three reasons:

- The primary purpose of determining PCB concentrations in selected organisms is to estimate potential dose through dietary exposure for consumers of contaminated prey. Top predators, by definition, are unlikely to be regularly consumed by other organisms.
- Data are unavailable to adequately interpret whole body or tissue PCB concentrations for these or closely related species. Contaminant body burdens are not in themselves appropriate assessment endpoints and, in general, are not

useful without comparison to appropriately-derived toxicity data (i.e., effects related to body burden concentrations).

- The primary risks associated with PCB contamination to top predators are through ingestion of PCB-contaminated prey, and available toxicity data primarily relate toxic effects to dietary dose rather than to PCB concentrations in whole body or specific tissue type.

For these reasons, estimations of the average potential daily dose (APDD) from ingestion of contaminated prey are used to assess potential PCB-related risks for the great horned owl, red fox, and bald eagle.

Input Parameters and Assumptions
The following subsections show the model input parameters, as well as assumptions made for each. **Appendix C** includes all input parameters and associated assumptions.

PCB Concentration. PCB concentrations are based on the U95 concentration of PCBs in abiotic media (surface water, streambed and floodplain sediment, and surface soil) of concern. These values are based on specific terrestrial and aquatic biota sampling areas (TBSAs and ABSAs), as described in the Biota Sampling Plan (CDM, 1993). Where data allow, U95 values are also used to describe PCB concentrations in biological tissues. Where data are more limited (e.g., terrestrial biota), maximum detected values are used for the reasons discussed previously. Values are in mg PCB/L for surface water and mg PCB/kg for sediment, surface soil, and biological tissue.

PCB concentrations in surface water (mg/L), streambed and floodplain sediment (mg/kg), and surface soil (mg/kg) are based on measured values. PCB concentrations in biological tissue (mg/kg) are estimated for aquatic organisms considered representative of lower trophic levels. These organisms include algae, aquatic macrophytes, and aquatic (benthic and water column) macroinvertebrates. In addition, PCB concentrations are estimated for terrestrial macrophytes and American robin from location-specific PCB concentrations in site media and literature-based data such as dietary fraction. Whole body PCB concentrations for earthworms, all fish species, muskrat, mink, and mice are based on the ABSA- or TBSA-specific maximum measured whole body PCB concentration for these organisms. PCB concentrations were neither measured nor estimated in the remaining three species (great horned owl, red fox, bald eagle) for the reasons cited previously.

Exposure Media. Exposure media represent the primary media to which specific receptors or categories of receptors may be exposed. These media include surface water, streambed and floodplain sediment, and surface soil.

Bioconcentration or Bioaccumulation Factor. Bioconcentration factors (BCFs) are based on the ratio of tissue contaminant concentrations in species of concern (mg/kg) to contaminant concentrations in surface water (mg/L). Bioconcentration considers only direct uptake from water, and does not include uptake from food. In general, BCFs are used for aquatic plants, aquatic invertebrates, and fish, and are based on laboratory tests in which sediments and contaminated prey are absent. Some BCFs presented in **Appendix C** are based on literature-based values and are applicable where specific biota such as algae, aquatic macrophytes, and aquatic invertebrates were not sampled. Laboratory-derived BCFs may not reflect bioconcentration potential under field (i.e., natural) conditions. For this study, the uptake of PCBs by algae, aquatic macrophytes, and aquatic invertebrates is estimated from appropriately-derived (i.e., following EPA guidelines) geometric mean BCFs in the literature, while BCFs (actually BAFs, see below) for fish are calculated from site-specific measured U95 PCB concentrations in surface water and fish. There is therefore a different level of confidence in the calculated BAFs for fish compared to BCFs for algae, aquatic macrophytes, and aquatic invertebrates. Confidence in the field or site-specific BCFs is increased because these data reflect uptake from all sources, not just water. Confidence in these same values is decreased because the fish and surface water data were not collected at exactly the same times and locations. These relationships are, however, considered useable because the surface water and fish data were collected within approximately the same time period and are ABSA-specific.

Bioaccumulation factors (BAFs) are similar to BCFs except that they reflect uptake from both food and water. The uptake of contaminants by fish and other aquatic organisms exposed to contaminated surface water, sediment, and prey in the field is best described using BAFs rather than BCFs.

BAFs can also be used to describe the soil-to-plant transfer of contaminants in terrestrial systems. For this assessment, BAFs are estimated for terrestrial macrophytes based on literature values for PCB transfer from surface soil to terrestrial plants. Limited data exist for deriving BAFs for terrestrial plants exposed to PCBs in soil. It is generally believed that PCBs do not accu;mulate in plants to the extent they can in animals. Some studies do indicate, however, that certain terrestrial plants can accumulate PCBs from soil to a concentration greater than the original soil concentration (i.e., BAF>1). Trapp et al. (1990) presents the results of two experiments in which the average plant PCB concentration was approximately 1.3 times that of the soil in which the plant was grown. Pal et al. (1980) described biomagnification factors (BFs) for several plant species. As expected, most terrestrial species accumulated PCBs from the soil at a BAF (or BF) of less than 1.0. However, included in this list of BFs for several plant species are two results that support a higher BAF for some species. Carrots, for example, accumulated PCBs from the soil at a factor of about 0.25, while weeds exposed in the same study accumulated up to a factor of 0.96 times the soil concentration (i.e., BAF=0.96). Weeds exposed in a study focused on sugarbeet accumulation of PCBs took up PCBs from the soil at a factor of 0.80 (BAF=0.80). Much higher BAFs are described by Pal et al. (1980) for aq;uatic plants and riparian plants that occur in wet soils or are frequently flooded. BAFs for strictly terrestrial plants are expected to be less than 1.0 expect for certain plant species. This ERA uses the BAF of 1.3 as described in Trapp et al. (1990) with the recognition that this BAF may overestimate PCB uptake for most terrestrial plant species but may under-estimate PCB uptake for riparian species or those that occur in frequently wet soils.

BAFs are calculated from measured PCB concentrations for the remaining aquatic, semi-aquatic, and terrestrial species. In cases where more than one media type is identified as a potential source of PCB contamination, BAFs are based on the primary exposure media. In other cases, BAFs are not calculated at all. For example, mink feed on a wide variety of aquatic, semi-aquatic, and terrestrial animals. Because PCB contamination in surface water, streambed and floodplain sediment, and surface soil can all contribute to PCB contamination of mink tissue through ingestion and bioaccumulation/ biomagnification, it is inappropriate in these cases to calculate BAFs. The relative contribution to measured PCB concentrations in certain sampled biota by each media type is likely to be highly variable, depending on season, seasonal diet, foraging range, contaminant distributions, etc. For this reason, it is also inappropriate to add or average media-specific BAFs (i.e., BAFs based on surface water PCB concentrations, on sediment PCB concentrations, and on surface soil PCB concentrations) for a single species where multiple exposure sources are identified because the relative contribution from each contaminant source is unknown. Calculated media-specific BAFs are most useful for assessing relative differences in uptake between species that are exposed primarily to one type of exposure media. For example, whole body PCB concentrations measured in smallmouth bass probably reflect uptake primarily from surface water but also from streambed sediment, sediment interstitial water, and prey to lesser degrees. No single media-specific BAF based on field data can accurately reflect actual contaminant uptake or relative contaminant contribution where several major contaminant sources and pathways are identified.

Calculated aquatic (surface water) and terrestrial (surface soil) BAFs are based on TBSA/ABSA-specific PCB concentrations measured in abiotic exposure media and biota (**Table 4-6**), where these data are available. In addition, **Table 4-6** presents Biota/Sediment Accumulation Factors (BSAFs) for ABSAs where streambed sediment and fish were collected over approximately the same time period. BSAFs reflect the potential transfer of a contaminant in sediment to biological tissues. The confidence in the ABSA-specific BSAFs are increased by the relatively large amount of fish and sediment data collected over approximately the same time period from the same ABSA. Contributing to decreased confidence in these BSAFs is the fact that the fish and sediment data were not collected at exactly the same location and time. The latter is not considered a critical data gap because of the mobility of fish and the variability in sediment PCB concentrations within an ABSA.

Home Range. An animal's home range can greatly affect its degree of exposure. For example, animals with home ranges entirely within a contaminated area will have greater exposure potential than animals with home ranges that substantially exceed the area of a contaminated site. This assumption may not always hold true, however, because home range values are often only estimates of the average area used by a particular species. It is not unreasonable to assume that an animal with a large home range will, at times, remain within a smaller area if that area provides adequate food and cover. In addition, models that estimate dietary exposures, including this model, are very sensitive to variability in home range estimates. Average home ranges for adult animals are presented in the model.

Site Foraging Frequency. Standard practice in assessing dietary exposures for wildlife include the derivation of site foraging frequency (SFF). This term is used to describe the ratio of the site area to the average home range for the species of concern. As commonly used, SFF values range from 0 to 1.0. It is apparent that animals with large home ranges are less likely to be significantly exposed to site-related contamination than animals that live entirely within site boundaries. However, as stated above, the use of home ranges for estimating exposure likelihood has certain critical limitations. First, home range estimates are based on overall use, yet certain individuals or populations may use smaller areas for foraging and cover if conditions are suitable. Also, dietary exposure models are extremely sensitive to variability in the input parameter identified here as SFF. It is not uncommon for dietary exposure models to predict zero or nearly no risk for species associated with highly contaminated sites solely because their average home range is very large. The API/PC/KR is large, and areas of PCB contamination are not evenly distributed in size or location. Thus, accurately correlating home range to site area is difficult at this site for species with large home ranges. However, this ERA focuses on those species who would primarily spend all or most of their time within the Kalamazoo River corridor.

Finally, the methods for determining home ranges are not intended to support the specific needs of ecological risk assessment. Home range sizes, which are presented in **Appendix C,** are often determined by locating nests, dens, or spawning areas for species of concern and then recording the locations of individual organisms observed in the area of the nest or den. Locations of individual organisms observed are then plotted on a map and connected by lines forming a polygon, with the nest or den located within the polygon. The area of the resulting polygon is considered to be a home range. This method does not consider frequency and size of foraging areas within the estimated home range, and therefore may be inappropriate for ecological risk assessment use. For the reasons cited, this assessment sets the SFF to 1.0 for all species for which dietary exposure is calculated. Although this adds conservatism to the model, it is considered prudent to prevent gross underestimations of potential risks for some ecological receptors.

Dietary Fraction. Dietary fraction is an estimate of the fraction of total diet contributed by each prey type. For this study, estimates of dietary fraction are based on values reported in the literature. Where more than one literature source of dietary information is available, estimates are based on the average of all relevant literature sources or the values most relevant to Western Michigan.

Average Ingestion Rate. Average ingestion rates (g/d) are determined for species of concern from values in the literature.

Table 4-6
Calculated Aquatic BCFs[1]/BSAFs[1] and Terrestrial BAFs[1] for Representative Food Web Species
(Based on primary exposure media)

Location	SM Bass BAF (SW)	SM Bass BSAF (SED)	Sucker BAF (SW)	Sucker BSAF (BSAF)	Carp BAF (SW)	Carp BSAF (SED)	Earthworm BAF (SS)	White-footed/ Deer Mouse BAF (SS)
ABSA 3	305,000	0.9	47,000	0.1	547,000	1.6		
ABSA 4 TBSA 10	113,000	0.5	156,000	0.7	1,000,000	4.7	0.07	0.03
ABSA 5	NA	0.1	NA	0.2	NA	0.9		
ABSA 6	NA	0.3	NA	0.2	NA	1.0		
ABSA 7	235,000	0.4	88,000	0.2	404,000	0.8		
ABSA 8 TBSA 3, 5	NA	1.2	NA	0.1	NA	1.1	0.113 (TBSA 3) 0.078 (TBSA 5)	0.016 (TBSA 3) 0.013 (TBSA 5)

ABSA 9	342,000	2.6	42,000	0.3	375,000	2.9		
ABSA 10 TBSA 1	NA	NA	NA	NA	NA	NA	0.109	1.52
Average BAF/BSAF	249,000	0.88	83,000	0.28	583,000	1.9	0.09	0.40

[1]BCFs/BAFs based on U95 PCB Conc (biota) / U95 total PCB Conc (exposure media)
Data from **Table 4-5**
Values are derived only for locations where reasonably synoptic data were collected
Values are rounded to the nearest one thousand.

SW: Surface Water
SED: Instream Sediment
SS: Surface Soil

NA: Not Applicable because 1) media quality and/or biological data not collected or 2) PCBs were not detected in sampled biota.

Average Body Weight. Average body weights (g) for representative adult organisms are based on values presented in literature sources. Where more than one source was consulted, the value used is based on the average of all species-specific adult body weights presented. In some cases, average body weights can be substantially different for males and females of the same species. Where this is the case, values used are based on the average of values reported for adult males and females.

Model Output

As stated above, the primary model output is an estimate of the average potential daily dose (APDD, mg PCB/kg BW-d) for upper trophic level organisms from ingestion of contaminated prey. This value is not determined for lower trophic level organisms (e.g., algae, macroinvertebrates, earthworm, forage fish) or game and rough fish because either it is not applicable (e.g., algae) or input parameters (e.g., ingestion rates) are generally unknown or associated with a high degree of uncertainty. APDD values may over- or underestimate actual PCB doses because of site-specific diet or foraging habits. Also, actual PCB doses probably vary seasonally and spatially.

For organisms for which APDD is not calculated, risk estimations are based on comparisons of exposure point concentrations of PCBs (e.g., PCB concentration is surface water) to LOAECs, criteria, or recommended limits.

Average Potential Daily Dose. APDD, (mg PCB/kg BW-d) is calculated from the equation described previously, and serves as the primary output of the PCB Food Web Model. This value is used to estimate potential risk to upper trophic level organisms from ingestion of contaminated prey by comparison with critical dietary concentrations.

Toxicity Assessment

The potential toxicity of PCBs to representative organisms is evaluated by comparing measured PCB concentrations in abiotic media or prey, or estimated PCB concentrations in prey, with appropriate media-specific criteria (e.g., AWQC) or species-specific critical effects concentrations (e.g., LOAECs). Although considered part of the food web model as a preliminary evaluation, these data are further discussed in the Effects Assessment portion of the ERA. The effects assessment also discusses other effects data used in the Risk Characterization phase of the ERA, including site-specific values with which overall risks to ecological receptors are evaluated.

Lowest Observed Adverse Effects Concentration (LOAECs). LOAECs are obtained from the literature for species of concern or for closely related species that are expected to exhibit toxicologically similar responses to PCB exposures. Species-specific LOAECs are compared to measured or estimated PCB concentrations from similar routes of exposure (e.g., direct contact or ingestion of food items) for selected species. Specific LOAECs selected for this study include the lowest effects concentrations from toxicity tests conducted with species of concern, and primary data sources are studies referenced in EPA contaminant-specific criteria documents (aquatic organisms) and U.S. Fish and Wildlife Service contaminant hazard review documents (terrestrial organisms). LOAECs are associated with adverse effects; therefore, PCB concentrations at or near the relevant LOAECs are associated with some risk. Concentrations of PCBs that are associated with no risk (no observed adverse effect concentrations or NOAECs) are generally unavailable. NOAECs are commonly estimated by (LOAEC/10), although Giesey et al (1994) recommends the use of LOAEC/3 for estimating NOAECs for mink exposed to PCBs through diet. This ERA uses LOAEC/10 to estimate NOAEC, even though LOAEC/3 was considered for mink with dietary exposures.

Criteria or Recommended Limits. In some cases, criteria (e.g., AWQC) or maximum allowable limits (e.g., those recommended for the protection of sensitive birds or mammals) have been established for species or other taxa of concern. Where such values are available, they are presented in the food web model for comparison to measured or estimated PCB concentrations determined in this study. Criteria and limits presented in **Appendix C** are not site-specific but are instead based on general toxicological data. The comparisons between toxicological data from the literature and exposure data for this site are used to evaluate reasonable maximum exposures for the API/PC/KR, based on U95 PCB concentrations in abiotic and most biological media. A comparison of arithmetic average PCB exposure data to toxicological data would have only limited usefulness for a large and diverse site like the API/PC/KR. The API/PC/KR is associated with highly variable PCB concentrations from one area to another, and average measured concentrations of PCBs are not likely to represent the true average or especially the reasonable worst-case exposure. U95 and in some cases maximum ABSA- and/or TBSA-specific exposure concentrations are therefore preferred for evaluating potential effects in ecological receptors. This ERA develops site-specific threshold values, presented in the Effects Assessment of the ERA, to assess potential impacts to representative biota of concern. These site-specific threshold values or effects concentrations consider measured PCB concentrations in exposure media and food items as well as site-specific bioaccumulation in sampled biota. Risk estimates for species/organisms of concern are based on site-specific threshold values where data are available because there is more confidence in site-derived data compared to more general criteria or effects concentrations, such as those preliminarily presented in **Appendix C**. Where site-specific data are unavailable, general effects data such as AWQC, Great Lakes Initiative (GLI) values, or interim sediment quality criteria are used to evaluate potential risks. Examples of more general effects data are presented in the food web model, **Appendix C**. Site-specific effects data are presented in Section 4.2, Ecological Effects Assessment, and are further discussed in Section 5, Risk Characterization, where risk estimates and proposed cleanup goals based on ecological risk are presented.

An interpretation of the output of the food web model **Appendix C** is presented in the Risk Characterization section of the ERA. The Risk Characterization section discusses the results of the food web model and integrates exposure and effects data to estimate risks to ecological receptors of the API/PC/KR. Effects assessment follows an analysis of uncertainties associated with exposure analysis and the food web model.

4.1.6 Uncertainty Evaluation - Exposure Assessment

Sources of uncertainty in the exposure assessment include the values used to represent the magnitude and distribution of media-specific contamination. Obviously, all media can not be sampled at all locations, and data interpolation and/or extrapolation is necessary. It is expected that the samples collected have been appropriately analyzed to adequately describe the nature and extent of PCB contamination at the API/PC/KR. Uncertainty in this assessment is decreased by the biological sampling specifically designed to support food web modeling and to support descriptions of the magnitude and distribution of PCB contamination at the API/PC/KR. Because ABSA and TBSA-specific sampling was relatively complete for abiotic media, the use of U95 concentrations of PCBs in SW, SED, FP SED, SS and most biota minimize the chance that risk estimations based on the selected exposure concentrations have been greatly under- or over-estimated.

Another major source of potential uncertainty in the ERA is the food web model. All models, including simplified models such as the one described herein, are associated with uncertainty. In general, more complex bioenergetic-type models have greater potential to accurately estimate contaminat transfer between environmental compartments but also have greater potential to introduce unacceptable levels of uncertainty unless critical information on site specific input parameters are available. For example, aquatic food web models based on bioenergetics have been established that calculate biomagnification factors (BMFs) for organic contaminants from exposure media through all major trophic levels to top predators. These models often require the use and evaluation of input parameters that are currently unknown, such as contaminant depuration rates for a particular species. Values for other species or even other chemicals are sometimes used to represent the required input parameter. Models may also be sensitive to slight differences in input parameter values, and results can, therefore, be highly uncertain. The uncertainty in resulting BMF estimations for higher trophic level organisms are also magnified because the model is based on addition and multiplication of values from lower trophic levels. For these reasons, complex computer-based food chain models are not considered appropriate for this assessment.

Although every caution was taken in this assessment to limit uncertainty as much as possible, simple models can also be associated with uncertainty. Where potential levels of uncertainty could adversely affect the results of the assessment, conservative approaches were taken that may result in over-protection of some local species. For example, many simple food chain models commonly predict, largely as a result of home range estimates, little or no risk to top predators from ingestion of contaminated prey. The site foraging factor (SFF) calculated from large home range estimates can therefore "drive" the model output (i.e., the APDD) for certain potentially important species. As discussed above, the foraging behavior of individual organisms and even populations are sufficiently unknown to warrant a more conservative or protective approach. To err on the side of over-protection is considered prudent and, in fact, follows regulatory guidance.

The most likely causes of uncertainty in this assessment are the variability of values associated with certain input parameters, especially values used to describe the distribution of PCB contamination in various media. Using U95 values for the larger abiotic and biological media data set and maximum values for the smaller biological data sets is expected to limit uncertainty and risk under-estimation to an acceptable degree. Literature values for BCFs and, to a lesser degree dietary fractions, are also critical with regard to potential for uncertainty due to uncertainties associated with laboratory to field extrapolations. There is more confidence in values used to represent species-specific ingestion rates and body weights because, in most cases, there is reasonable concurrence by investigators. Finally, LOAECs, criteria, and recommended limits are based on national databases or are intended to protect large and diverse groups of organisms (i.e., aquatic life, mammals, etc.). These values may therefore be over- or under-protective of certain local species and/or populations.

Uncertainty in this assessment regarding field-generated data is likely to be limited mostly to uncertainties in the representativeness of biological samples. Such samples are expected to be highly variable even within a species because of differences in individual behavior and activities. Even these factors are expected to vary from season to season and from one location to another. These types of uncertainties provide one basis for using maximum detected concentrations of PCBs in biological tissues for risk estimations. It is therefore more unlikely that this assessment underestimates risk because conservative approaches such as these are used where appropriate, and any uncertainties are provably biased towards over-protection.

4.2 Ecological Effects Assessment

Effects Assessment includes an evaluation of data sources and data types, and presents potential media-specific and stressor-specific ecological effects concentrations for PCBs, the primary chemical stressors identified at the API/PC/KR. These data serve as major components of stressor-response profiles, which describe the relationship between ecological stressors and effects.

4.2.1 Evaluation of Effects Data

This section of the ERA describes and provides support for the sources and types of effects data (e.g., toxicity data) selected for use in the ERA. Data sources and types are described on a media-specific basis. Selected measurement endpoints or effects data are based on relevance to the API/PC/KR, and site-related stressors and receptors are considered in this selection. These data are directly applicable to assessment endpoints and remedial action objectives determined for the API/PC/KR which include:

(1) the preservation of the survival, growth, and reproduction of wildlife,

(2) the establishment and maintenance of a healthy and diverse aquatic ecosystem in and adjacent to the API/PC/KR,

(3) reductions in PCB concentrations through removal and destruction of contaminated media, and

(4) reductions in PCB concentrations in fish and wildlife such that human consumption restrictions can be lifted.

Some effects data are more relevant and useful than others. For example, effects data are unavailable for certain receptors or receptor groups associated with the API/PC/KR. In these cases, the effects assessment is based on more general effects data available in the literature. Finally, site-specific data, such as bioconcentration and bioaccumulation factors determined by recent sampling and analysis of media and biota, are used to support estimations of risks for ecological receptors. Overall, the effects assessment provides a weight-of-evidence approach based on multiple data sources to evaluate risks. This approach is especially important where relevant site-specific data are limited. The availability of effects data are media specific, and relevant data sources for each media of concern are presented below.

Effects Data Sources (Surface Water)

Acceptable and relevant effects data for PCBs in surface water are generally available. Most of the surface water toxicity data used in this ERA are from the EPA Ambient Water Quality Criteria (AWQC) document for Polychlorinated Biphenyls (EPA 1980) and Polychlorinated Biphenyl Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review (Eisler 1986). The chronic AWQC derived by EPA is based on protection of mink (most sensitive wildlife species tested) and considers fish ingestion by mink. Finally, a site-specific threshold PCB concentration in surface water for the API/PC/KR is calculated to protect resident mink, the most sensitive of tested species. This value is based on the average site-specific carp BAF and on the geometric mean of a range of dietary threshold concentrations, derived for prey consumed by mink.

Relevant and useful threshold concentrations derived for dietary items of mink include the results reported in four separate studies in which mink were fed diets containing PCBs and adverse effects were observed. These studies include the following:

- Ringer (1983) fed mink a diet containing 0.64 mg PCB/kg fresh weight diet and observed severe reproductive effects in mink. This value is identified as an LOAEC, and a corresponding NOAEC is estimated at 0.064 mg PCB/kg fresh weight diet, based on the standard practice of NOAEC = LOAEC / 10.

- The Great Lakes Initiative (GLI) identified a maximum acceptable tissue concentration (MATC) for dietary items of mink of 2.0 mg PCB/kg fresh weight diet. This value is identified as most closely representing an LOAEC, and a corresponding NOAEC is estimated at 0.2 mg PCB/kg fresh weight diet.

- Heaton (1992) determined a dietary LOAEC for mink of 0.72 mg PCB/kg fresh weight diet. The corresponding estimated NOAEC is 0.072 mg PCB/kg fresh weight diet.

- Restum et. al. (1998) determined a dietary LOAEC for mink of 0.25 mg PCB/kg fresh weight diet. The corresponding estimated NOAEC is 0.025 mg PCB/kg fresh weight diet.

A geometric mean of the four reported LOAECs for PCBs in diet (0.25, 0.64, 0.72, 2.0 mg/kg) was calculated for this ERA because there is no evidence that any of the four reported LOAECs is superior or more appropriate than any other value. The fact that all of the reported LOAECs are quite similar increases the confidence in each of the values. The geometric mean of the four LOAECs presented above is 0.69 mg PCB / kg fresh weight diet.

Similarly, a geometric mean of the four estimated NOAECs was derived, and this value is 0.069 mg PCB/kg fresh weight diet. Based on the definition of NOAEC and LOAEC, it is estimated that mink diets containing 0.069 mg PCB/kg fresh weight or less would not cause measurable adverse effects in mink. Contrastingly, mink diets containing 0.69 mg PCB/kg fresh weight or greater would be expected to cause unacceptable adverse effects in mink.

An appropriate threshold value for mink diet would be expected at some value between 0.069 and 0.69 mg PCB/kg fresh weight. It cannot be determined from available data whether the actual threshold value where adverse effects begin to be observed is just below the LOAEC, just above the NOAEC, or at some point between the two values. Because this ERA is not a screening level ERA, ultra conservative approaches and assumptions cannot be justified. The order of magnitude difference between the geometric mean LOAEC and NOAEC suggests that using the estimated NOAEC may be overly conservative. Alternatively, using an LOAEC as a threshold is likely to be insufficiently protective. Therefore, this ERA follows the approach use by EPA for determining MATCs (tissue) and chronic values (CVs) for deriving water quality criteria by calculating the geometric mean of the NOAEC and the LOAEC. The geometric mean of 0.069 and 0.69 mg PCB/kg fresh weight diet is 0.22 mg PCB/kg fresh weight diet. This value serves as the estimated threshold or "not-to-exceed" value for dietary items of mink in this ERA.

Additional support for using 0.69 mg/kg as a dietary LOAEC and 0.069 mg/kg for a dietary NOAEC for mink was obtained from Giesy et al. (1994). In this study of contaminants in fish from Great Lakes-influenced sections and dams of Michigan rivers, the authors used a dietary NOAEC of 0.072 mg/kg (wet weight). Using the same approach recommended by EPA and used in this ERA, this value would equate to a dietary LOAEC of 0.72 mg/kg. Giesy et al. (1994) state that 0.072 mg/kg serves as the best estimate of the dietary NOAEC for mink.

This ERA independently confirms that a dietary NOAEC of about 0.07 mg/kg is appropriate, and a corresponding LOAEC is estimate at approximately 0.7 mg/kg. Because of the variability in exposure durations and endpoints in the studies described above, this ERA sets the dietary threshold for mink at the geometric mean of the NOAEC and LOAEC. As such, this threshold would be similar to concentrations that cause or begin to cause adverse sublethal effects. This value can therefore be considered a threshold where significant adverse effects may begin to be experienced by mink exposed to this dietary PCB concentration.

The 0.22 mg PCB/kg dietary threshold for mink is also used in this ERA to calculate a threshold surface water concentration that is protective of mink that consume PCB-contaminated fish. The average BAF for carp, considered a key dietary item for local mink, was determined from the field data used to support this ERA. This mean BAF is 583,000, based on U95 total PCB concentrations for whole body carp and U95 total PCB concentrations in surface water. This BAF and the dietary threshold of 0.22 mg/kg is used to calculate the surface water (SW) threshold as follows:

$$\text{SW threshold} = \frac{\text{0.22 mg PCB/kg fresh weight diet}}{583{,}000}$$

$$= \text{0.000000377 mg PCB/L water}$$

$$= \text{0.00038 ug PCB/L water}$$

The surface water threshold calculated to prevent fish tissue from containing more than 0.22 mg PCB/kg wet weight is 0.00038 ug/L. This value is also discussed in Section 5.5.1. **Table 4-7** includes specific data sources and selected measurement endpoint data from these sources, including the site-specific SW threshold of 0.00038 ug PCB/L.

Effects Data Sources (Sediment)

Universally-accepted biological effects concentrations for most sediment contaminants have not been developed for ecological receptors. In general, the most useful data on potential sediment toxicity is obtained from site-specific studies using site sediments and resident or representative test species.

Site-specific sediment toxicity data are unavailable for this ERA. The evaluation of the potential toxicity associated with PCB contamination of onsite streambed sediments is based on the comparison of PCB concentrations in API/PC/KR streambed sediments to various relevant data. These include background concentrations. EPA-recommended and site-specific sediment concentrations based on the equilibrium partitioning (EP) approach (EPA 1988b) using both literature-based and measured (site-specific) input parameters (e.g., sediment/water partition coefficients or Kds), and other relevant data from sources such as Long and Morgan (1991) and Persaud, et al. (1993). Databases such as that of Long and Morgan (1991) have been established that describe the co-occurrence of chemical contaminants and apparent biological effects, and others (e.g., Persaud, et al. 1993) include interim criteria for contaminants in sediment. Although the data presented in these more general (i.e., non-site-specific) databases are associated with certain limitations and uncertainties, they can contribute useful information to the overall evaluation of potential sediment toxicity using a weight-of -evidence approach. Such an approach is used in the risk characterization phase of this ERA, where sediment toxicity data are supplemented with comparisons between onsite PCB concentrations in API/PC/KR sediments and concentrations that either co-occur with observed adverse biological effects (Long and Morgan 1991) or have been established as interim sediment quality criteria by Ontario, Canada (Persaud, et al. 1993). The same four mink dietary studies presented in the preceding discussion of surface water data sources are used for deriving a site-specific threshold for PCBs in sediment that protect mink, the most sensitive organism tested with PCBs.

The calculated site-specific surface water threshold of 0.00038 ug PCB/L is used along with the mean site-specific sediment/surface water partition factor (Kd) of 301,712 (rounded to 302,000) to derive a site-specific sediment threshold value. This derivation follows:

SED threshold	=	SW threshold * Kd
	=	0.00038 ug PCB/L * 302,000
	=	114.8 ug PCB/kg sediment
	=	0.115 mg PCB/kg sediment

The calculated site-specific threshold for PCBs in sediment, based on preventing fish tissue from containing more than 0.22 mg PCB/kg wet weight and site-derived BAFs from surface water is 0.115 mg PCB/kg sediment. This value, rounded to 0.12 mg/kg, is also discussed in Section 5.5.1.

Adding the the weight-of-evidence approach used in this ERA, another method was used to estimate a site-specific PCB threshold for instream sediments. This alternative method is based on the average biota/sediment accumulation factor

(BSAF) for carp (1.9). This value is used to derive a site-specific sediment threshold for PCBs as follows:

SED threshold = Fish Tissue Threshold / BSAF

= 0.22 mg PCB/kg wet weight whole body fish tissue / 1.9

= 0.116 mg PCB/kg sediment

Rounding to the nearest 0.01 mg, this sediment threshold is the same number as derived using the surface water and Kd input parameters (0.12 mg/kg). Both approaches use the same 0.22 mg/kg whole body fish tissue PCB limit, but the second approach is based on only fish/sediment relationships while the first considers surface water/sediment relationships. The fact that the same number is derived using different approaches provides added confidence in the use of 0.12 mg PCB/kg sediment as a valid threshold for PCBs in sediment.

Table 4-7 includes selected measurement endpoint data for streambed sediments based on these data sources and on site-specific calculations, including the site-specific threshold for PCBs in sediment of 0.12 mg/kg.

Effects Data Sources (Surface Soil and Floodplain Sediments)
Similarly, accepted critical effects concentrations for chemicals in surface soils and floodplain sediments have not been developed solely for the protection of ecological receptors. As for sediment (streambed) contaminants, site-specific data are considered to be the most useful and appropriate for evaluating the potential toxicity of API/PC/KR surface soils and floodplain sediments. Such data are not, however, available, and three other approaches are used in the risk characterization phase of this ERA.

First, PCB concentrations in onsite surface soil and floodplain sediments are compared to background concentrations based on relevant and available data. Second, more general data sources on the potential hazards of contaminated surface soil and floodplain sediments are used to additionally evaluate the potential toxicity of API/PC/KR surface soil and floodplain sediment. Critical threshold levels for chemicals in surface soils, based on several soil functions including the protection of wildlife, have been derived by and used in various countries (e.g., Norway; The Netherlands; West Germany; England; Ontario and Quebec, Canada) for several years (Siegrist 1989). The most appropriate critical threshold levels from sources such as these, based on general acceptance and data quality and quantity, are used to evaluate the potential toxicity of PCBs in surface soil and floodplain sediment. Evaluation of these alternative data sources suggests that the Ontario and Quebec (Siegrist 1989) values are the most appropriate and useful for this ERA. Preferred data (e.g., site-specific soil toxicity data) are unavailable, but the comparisons of PCB concentrations in onsite surface soil to threshold values (e.g., those derived by Ontario and Quebec) contribute to the weight-of-evidence regarding the potential toxicity of API/PC/KR surface soils and floodplain sediments. Because the soil threshold values presented in Siegrist (1989) and the sediment toxicity database of Long and Morgan (1991) are general and not site-specific, they can only contribute to the weight-of-evidence concerning the potential toxicity of surface soil or sediment. They are not, therefore, used alone to definitively describe API/PC/KR surface soil or floodplain sediment as toxic.

Further adding to the weight-of-evidence approach is the calculation of critical threshold values (TVs) for PCBs in surface soil. These TVs are species-specific, and are based on back calculation from species-specific lowest observed adverse effects concentrations (LOAECs). Derived TVs are only applicable to terrestrial species that feed on terrestrial prey, and are therefore calculated from surface soil PCB concentrations only.

It is clearly inappropriate to calculate surface soil TVs for aquatic species. Similarly, it is inappropriate to calculate surface soil TVs for semi-aquatic and terrestrial species that are exposed to PCBs primarily through aquatic food chains (i.e., ingestion of aquatic vegetation or prey). For these species (e.g., muskrat, mink), a surface soil TV of even zero PCBs provides little or no protection because the primary exposure route is not addressed. The equation used for calculating soil sediment (SS) TVs is:

TV = (*LOAEC or NOAEC/Dietary PCB Dose*) * *SS PCB Conc*

Where:

LOAEC or NOAEC	=	Species-specific dietary PCB concentration (mg PCB/fresh weight diet)
SS PCB Conc	=	U95 PCB conc (mg/kg) in SS
Dietary PCB Dose	=	Sum of (PCB Conc food item * *DF*)

PCB Conc food item is based on measured or estimated PCB Conc in food items. Estimated PCB Conc food item is based on the sum of (*BAF*DF*) for each food item.

BAF	=	species-specific bioaccumulation factor for each food item
DF	=	species-specific dietary frequency for each food item

4.2.2 Stressor-Response Profiles

Stressor-response profiles (**Table 4-7**) present critical effects data for relevant ecological receptors or appropriate surrogate species that may be exposed to PCBs at the API/PC/KR. The information presented in **Table 4-7** includes relevant toxicity data from literature sources and includes site-specific information to the extent possible. For example, site-specific toxicity values for surface soil are included, along with a threshold streambed sediment PCB concentration, based on site-specific sediment/surface water partitioning, that is protective of aquatic species and piscivorous wildlife. These profiles include information on the lethal and sublethal effects that may be exhibited by exposed organisms correlated to media-specific PCB concentrations. Because effects and other relevant data are sparse for individual Aroclors, and because concentrations of detected PCBs (e.g., Aroclor 1260) approach concentrations of total PCBs measured, all effects data are based on Total PCB concentrations. Likely responses to non-chemical stressors are not included in these profiles, but are qualitatively discussed below.

Siltation of Instream Substrate

Siltation, particularly as it contributes to the transport and deposition of PCB-containing residuals waste, may be contributing to ecological stress in the API/PC/KR. Siltation can result in decreased dissolved oxygen concentrations, greater concentrations of contaminants sorbed onto fine grained sediments and other fine particulate matter, and shifts in macroinvertebrate community structure. For example, certain worm species and midge larvae are better adapted to silt than are stoneflies, caddisflies, and mayflies. Areas of siltation are likely to be characterized by lower species diversity than that found in areas of gravel/cobble. Siltation can directly (by smothering) and indirectly (by changing prey availability and community structure) affect survival of benthic macroinvertebrates. Siltation can adversely affect fish reproduction and survival by smothering eggs and immature (prior to swim-up) fish. The paper waste residuals are very fine grained particles which are easily suspended in the water column and when deposited concentrate PCBs in the sediments.

Impoundment Structures/Dams

Impoundment structures or dams can affect the movement of fish in the river, the distribution of PCBs and the exposure potential for aquatic receptors. Although impoundment structures present barriers to fish migration, the greatest threats from these structures is that they form a sink for the PCB residual materials. PCB residuals behind the formerly impounded areas are constantly being eroded into the Kalamazoo River and Portage Creek, and some of which will become bioavailable to aquatic receptors. The impounded waters behind these structures provide excellent habitat for many game species and it is common to observe anglers at these locations. The exposure potential can be greater for both human and aquatic/terrestrial receptors at these sites.

Disturbed terrestrial/riparian habitat
Most soil-dwelling animals, especially those that have limited mobility, are likely to avoid some terrestrial areas because preferred natural soils are no longer available when covered with significant amounts of contaminated sediments. While the potential toxicity of contaminated soils and streambank sediments can not be ignored, it is likely that the physical presence of waste soils also affects habitat suitability for certain terrestrial organisms. Where terrestrial vegetation has either not been affected or has been re-established, a variety of terrestrial animals can find cover and food. Additionally, these disturbed areas are attractive sites for the development of "weedy" type plants, which can provide a food source for avian and terrestrial receptors.

4.2.3 Uncertainty Evaluation - Effects Assessment

In this section, the major sources of uncertainty in the effects analysis are identified and their potential impact on the ERA is evaluated. Media-specific toxicity data used in this ERA to describe the potential effects to ecological receptors are probably the primary source of uncertainty in the effects analysis.

Extrapolations are often used to relate measurement endpoints (e.g., lethal concentration) to assessment endpoints (e.g., macroinvertebrate abundance) or to relate one measurement endpoint (lethal concentration) to another (sublethal effects concentration). Extrapolations between taxa (e.g., species to species) or between responses (e.g., lethal to sublethal) are commonly used where specific data is limited. The use of these types of extrapolation is a commonly accepted practice, however may increase uncertainty in risk assessment. The use of extrapolated data are therefore limited as much as possible in this ERA.

Data based on studies specific to the API/PC/KR are preferred and are, therefore, used as much as possible in this ERA to minimize the uncertainties commonly associated with extrapolating toxicity or other data. Effects data for surface water and sediment contaminants are considered to be associated with low to moderate uncertainty, respectively. The unavailability of relevant site-specific surface water, sediment, and surface soil toxicity data increases uncertainty somewhat, but the availability of site-specific PCB concentrations in exposure media and resident biota helps minimize these uncertainties. There is considerably more uncertainty in the data used to evaluate the potential toxicity of contaminated surface soils because ecotoxicity data for terrestrial biota exposed to PCBs in surface soil are not as abundant as are data for evaluating PCBs in surface water and sediment.

Table 4-7
PCB Stressor-Response Profiles

Chemical Stressor	Media of Concern	Measurement Endpoint Concentrations	Measurement Endpoint Data Data Type/species/effects	References
Total PCBs	SW	0.00012 ug/L	Wildlife Protection Criterion for Surface Water - Michigan	Act 451 1994, Part 4
		0.00038 ug/L	Site-specific value to protect mink. Based on mean site-specific BAF for carp (583,000) and geometric mean dietary threshold for mink (0.22 mg/kg).	See text
		0.014 ug/L	Chronic Ambient Water Quality Criterion	EPA 1980
		0.14 ug/L	Lowest chronic value, freshwater aquatic plants	Suter and Tsao 1996
		0.2-9 ug/L	Range of chronic values (mean of ranges) for Aroclors 1242-1260, fathead minnow	EPA 1980
		0.8-15 ug/L	Range of chronic values (mean of ranges) for freshwater invertebrates	EPA 1980
Total PCBs	SED	0.0029 mg/kg	Freshwater Screening Level Concentration (SLC)	Long & Morgan 1991
		0.01 mg/kg	No Effect Level, benthic organisms, Ontario	Persaud et al. 1993
		0.054-3.1 mg/kg	Range of apparent effects concentrations (AET), multiple species	Long & Morgan 1991
		0.07 mg/kg	Lowest Effect Level, benthic organisms, Ontario	Persaud et al. 1993
		0.12 mg/kg	Calculated value to allow IW to remain below site-specific SW threshold (0.00038 ug/L)	EP Approach/Site-specific
		0.12 mg/kg	Calculated value based on site-specific BSAF for carp and fish tissue limit of 0.22 mg/kg	Site-specific
		0.37 mg/kg	Concentration at which adverse effects are always observed	Long & Morgan 1991
		0.4 mg/kg	Effects Range-Median (ER-M)	EPA 1988b See text -EP Approach*
		3.4 mg/kg	Calculated value to allow IW to remain below chronic AWQC (theoretical Kd)	EP Approach
		4.2 mg/kg	Calculated value to allow IW to remain below chronic AWQC (site-specific Kd: 302,000)	EP Approach
Total PCBs	FP	0.1 mg/kg	"A" concentration (background pollution), Quebec	Siegrist 1989
	SED	1 mg/kg	"B" concentration (threshold), Quebec	Siegrist 1989
	SS	0.7-7 mg/kg	Min and Max[1] calculated APt/PC/KR-specific threshold to protect songbirds (robin)	See text
		0.8-40 mg/kg[1]	Min and Max[1] calculated TBSA-specific TVs to protect small terrestrial mammals (mouse)	Siegrist 1989
		8-75 mg/kg	Min and Max[1] calculated API/PC/KR-specific threshold to protect terrestrial carnivorous mammals (fox)	See text
		10 mg/kg	"C" concentration, (contaminated), Quebec	See text
		35-349 mg/kg	Min and Max[1] calculated API/PC/KR-specific threshold to protect carnivorous birds (owl)	See text

SW: Surface Water **SED**: Sediment **FP SED**: Floodplain Sediment **SS**: Surface Soil

Equilibrium Partitioning approach (SED CONC=KD*IW CONC), (Site-specific: mean Kd=302,000, IW CONC=Chronic AWQC (0.000014 mg/l)

(Theoretical): SED CONC (mg/kg) = KD*IW CONC (mg/L)
KD = Koc * Foc
Foc = 0.082 (sitewide mean Foc)
KD = 2,944,422 * 0.082 = 241,443
log Koc = 0.937 log Kow - 0.006 (EPA Foc 1988b) = 6.469 (Koc = 2,944,422)
Mean log Kow (Aroclor 1260) = 6.91 (EPA 1988b)
SED CONC (mg/kg) = KD*IW CONC (mg/L
3.4 mg/kg = 241,443* 0.000014 mg/L

[1] Min and Max threshold based on NOAEC and LOAEC

As stated above, where possible, site-specific effects data are used to minimize uncertainty in the effects analysis. Because site-specific data are for the most part limited (to PCB tissue concentrations) or are unavailable (toxicity data), a weight-of-evidence approach is used to assess potential for ecological effects. The weight-of-evidence approach used in this ERA, which relies on ecological effects data from a large variety of appropriate and relevant data sources, decreases the overall uncertainty compared to assessments based on only one or a few data sources. Several of the data used to quantitatively estimate critical threshold contaminant concentrations (e.g., AWQC, LOAECs, site-specific tissue concentrations, Co-Occurrence Analysis (COA), Effects Range-Median (ER-M), and others) are often relatively similar in magnitude. These similarities allow greater acceptance of and support for each individual value, and in turn provides justification for the weight-of-evidence approach used in this ERA.

Section 5
Risk Characterization

Risk characterization integrates exposure data (e.g., PCB concentrations in surface water) and effects data (e.g., concentrations of PCBs in surface water that protect sensitive resident biota) to estimate risk. For this ERA, the integration of exposure and effects data includes but is not limited to the use ofsimple hazard quotients, where a single exposure concentration is divided by a single effects concentration. Although such quotients can be useful, limiting risk estimation to this simplistic approach fails to consider the variability and uncertainty in exposure and effects data. This ERA therefore supplements the hazard quotient method with other information to provide a weight-of-evidence approach that reduces uncertainty.

Contributing to the weight-of-evidence approach used in this ERA are (1) comparisons of key exposure data (e.g., mean, U95, maximum PCB concentrations in exposure media) to several relvant effects concentrations or thresholds; (2) the results of the food chain model that estimates PCB dose via dietary exposure; (3) qualitative evaluations of observations and discussions of ecological significance; and (4) hazard quotients using carefully selected exposure and effects data.

Risks for ecological receptors are assessed in this ERA on a media-specific basis. There is no appropriate method for combining risks from multiple exposure sources because the relative contribution to total risk from each source (e.g., surface water, sediment, soil, biota) is unknown. Also, the relative risk contribution from each source and for each species probably varies both spatially and temporally, primarily as seasonal migratory and dietary habits change.

5.1 Risks from Chemical Stressors

The primary risks to ecological receptors at this site are from chemical stressors. Although a large variety of chemical contaminants have been detected in onsite media and in resident biota, this ERA is focused on assessing the risks from PCB exposures via direct contact with surface water, streambed sediment, floodplain (exposed streambank) sediment, and surface soil, as well as ingestion of PCB-contaminated food items. Risks from drinking surface water and from incidental ingestion of sediment and soil are not evaluated in this ERA because such risks are likely to be much lower than the risks from direct contact with exposure media and ingestion of contaminated prey. As stated previously, this ERA is focused on the most important stressors (PCBs) and exposure pathways for resident ecological receptors.

The following discussions of media-specific risks are based on presentations of ABSA-specific arithmetic mean, U95, and maximum exposure concentrations and relevant effects concentrations from multiple sources. For estimating risks, the most useful comparisons of exposure and effects concentrations are based on U95 exposure concentrations and site-specific effects concentrations or thresholds. These comparisons best represent reasonable upper-bound estimates of risk for site receptors. Although less useful, comparisons of more general effects concentrations to arithmetic mean and maximum exposure concentrations are included in the following discussions so that other levels of site contamination can be evaluated.

5.1.1 Risk from PCBs in Surface Water (direct contact)

Figure 5-1 presents mean, U95, and maximum total PCB concentrations in surface water for all sampled ABSAs and Portage Creek. Also included in **Figure 5-1** are horizontal lines representing relevant effects concentrations for aquatic receptors. These effects concentrations, from lowest to highest PCB concentrations, are (1) the Michigan state water quality standard to protect wildlife (0.00012 ug/L), (2) the API/PC/KR-specific effects concentration to protect sensitive piscivorous consumers such as mink (0.00038 ug/L), (3) the EPA national chronic AWQC for PCBs (0.014 ug/L), (4) the lowest chronic value for aquatic plants (0.14 ug/L), and (5) the lowest chronic value for freshwater fish (0.2 ug/L). These effects concentrations are taken from **Table 4-7**, and represent the most appropriate effects concentrations of those presented in **Table 4-7.** Note that the lowest or first three effects concentrations listed are based on protection of wildlife rather than direct effects to aquatic biota. The latter two values are based on direct toxic effects to exposed aquatic biota.

Figure 5-1 reveals that all measured surface water total PCB concentrations exceed the Michigan water quality standard for the protection of wildlife. Non-detect values are included in the mean and U95 values as either half the detection limit or a randomly assigned value between zero and the detection limit, depending on data source. Nearly all surface water PCB concentrations exceed or approach the site-specific threshold calculated to protect mink (0.00038 ug/L). Nearly all surface water PCB concentrations collect from Portage Creek downstream to and including ABSA 11 exceed the EPA national chronic criterion for PCBs. Only occasionally have measured surface water PCB concentrations exceeded or approached chronic effects thresholds for fish or aquatic plants. Direct toxic effects to fish, invertebrates (chronic effects threshold 0.8 ug/L), or aquatic plants are therefore considered

Figure 5-1
Total PCB Concentration
API/PC/KR Surface Water

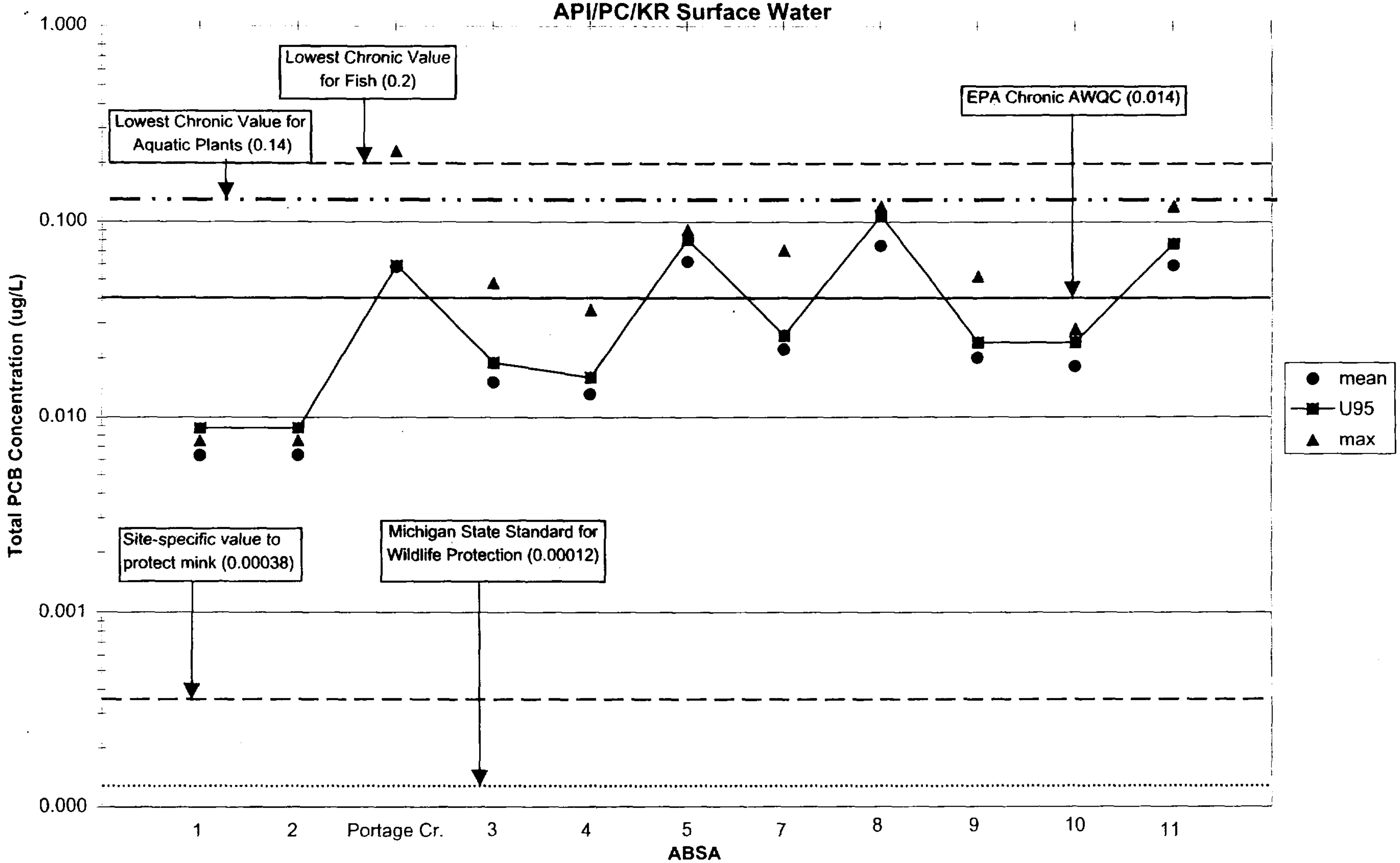
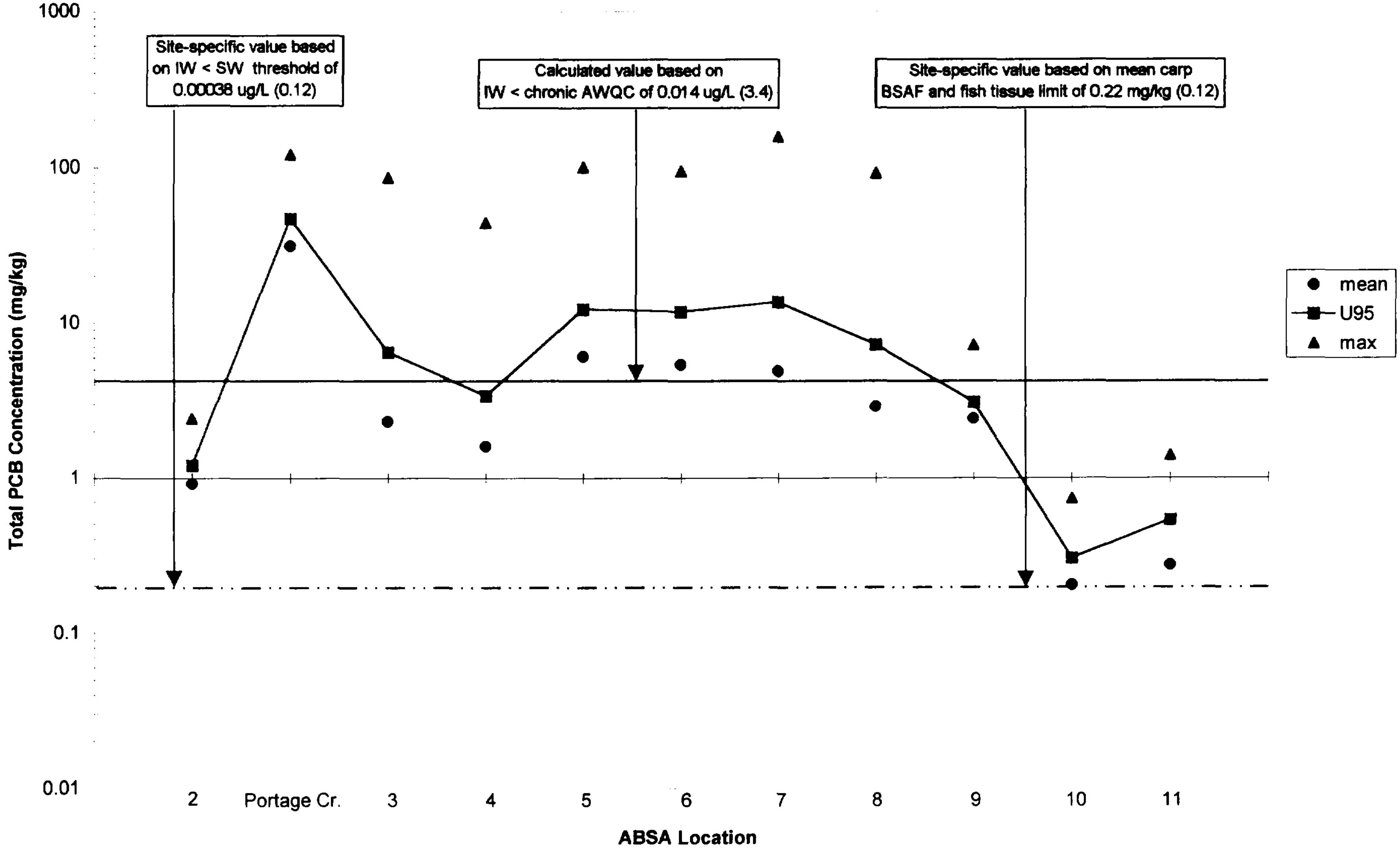


Figure 5-2
Total PCB Concentration
API/PC/KR Instream Sediment



unlikely except at specific locations or times when PCB water column concentrations are likely to be highest (e.g., during storm events).

5.1.2 Risks from PCBs in Streambed Sediment (direct contact)

Figure 5-2 presents mean, U95, and maximum total PCB concentrations in streambed sediment for all sampled ABSAs and Portage Creek. Also included in **Figure 5-2** are horizontal lines representing relevant effects concentrations for potential receptors. These effects concentrations, from lowest to highest PCB concentrations, are (1) the interstitial water (IW) concentration equal to the API/PC/KR-specific surface water threshold derived to protect sensitive piscivorous consumers such as mink (0.12 mg/kg), (2) the site-specific sediment threshold based on the mean BSAF for carp and the limit established for dietary items consumed by mink (also 0.12 mg/kg), and (3) the IW concentration equal to the chronic AWQC for PCBs based on site-specific sediment/water partitioning (3.4 mg/kg). These effects concentrations are taken from **Table 4-7**, and represent the most appropriate effects concentrations of those presented in **Table 4-7.**

Figure 5-2 clearly shows that mean, U95, and maximum streambed sediment total PCB concentrations exceed all three effects concentrations at Portage Creek and ABSAs 3-9. Total PCBs in streambed sediments at ABSAs 10 and 11 are below the more general effects concentration (3) described above, but exceed the more useful mink-based values of 0.12 mg/kg. PCB concentrations in API/PC/KR streambed sediments are likely to pose risks to sensitive benthic aquatic biota (e.g., macroinvertebrates) and water-column biota (e.g., invertebrates and fish) through release of PCBs from sediment particles. Also, sensitive piscivorous consumers such as mink are likely to be adversely affected by PCB-contaminated streambed sediments via the SED-IW-SW-fish pathway. The ingestion pathway is discussed in Section 5.1.4.

5.1.3 Risks from PCBs in Floodplain Sediment and Surface Soil (direct contact)

Figure 5-3 presents mean, U95, and maximum total PCB concentrations in floodplain sediment for all sampled areas. **Figure 5-4** presents similar values for PCB concentrations in surficial soil for all sampled areas. Also included in **Figures 5-3** and **5-4** are horizontal lines representing relevant effects concentrations for potential receptors. The effects concentrations for both surface soil and floodplain sediment, from lowest to highest PCB concentrations, are (1) the Ontario Ministry of the Environment "B" threshold for contaminated soils (0.1 mg/kg), (2) the minimum API/PC/KR-specific threshold to protect small omnivorous terrestrial mammals represented by white-footed and deer mouse (0.8 mg/kg), and (3) the minimum API/PC/KR-specific threshold to protect carnivorous birds, represented by great horned owl (35 mg/kg). These are considered the most appropriate effects concentrations, taken from **Table 4-7.**

Figure 5-3 reveals that most floodplain sediment total PCB concentrations exceed the Ontario "B" value threshold, while the mouse-based threshold is exceeded at ABSAs 7, 8, 10. Note that floodplain sediments were only collected at ABSAs 5, 7, 8, and 10. The owl-based threshold for floodplain sediments is exceeded only at ABSA 10. The Ontario "B" concentration is not derived solely for the protection of ecological receptors, and therefore is not as useful as the site-specific thresholds calculated for the protection of small omnivorous mammals and carnivorous birds.

For surface soils (**Figure 5-4**), limited sampling reveals potential for concern at *TBSA*s 3, 5, and 10. At these locations, surface soil PCB concentrations exceed the two most stringent thresholds described above ((1) and (2)). At no sampled locations is the owl-based threshold for surface soils exceeded. There may be similar cause for concern at other non-sampled locations. Surface soil data at TBSAs 1 and 11 suggest little cause for concern, based on limited sampling, at these locations. Surface soils and floodplain sediments have potential to pose risks to sensitive terrestrial receptors that consume PCB-contaminated plants and invertebrates. Terrestrial omnivores such as mice and terrestrial carnivores such as red fox might be at risk if they forage predominately in floodplain areas that are highly contaminated with PCBs. Foraging outside the floodplain, where surface soil PCB concentrations are lower and less variable than floodplain sediments, is likely to reduce risks to terrestrial omnivores and carnivores. Certain songbirds can be at substantial risk because PCB concentrations in surface soil and floodplain sediment are predicted to contribute to elevated PCB concentrations in terrestrial plants. These risks, and the considerable uncertainty associated with them, are discussed below in Section 5.1.4. In summary, onsite PCB risks to terrestrial biota, although possible, are expected to be much lower than risks to aquatic biota and consumers of aquatic biota. Contaminated surface water and streambed sediments are, therefore, of greater concern at this site than are floodplain sediments and surface soils. Floodplain sediments are of most concern because erosion and deposition into surface water is occurring. In this case, contaminated floodplain sediments can serve as a source of PCB contamination to surface water and streambed sediment.

Figure 5-3
Total PCB Concentration
API/PC/KR Floodplain Sediment

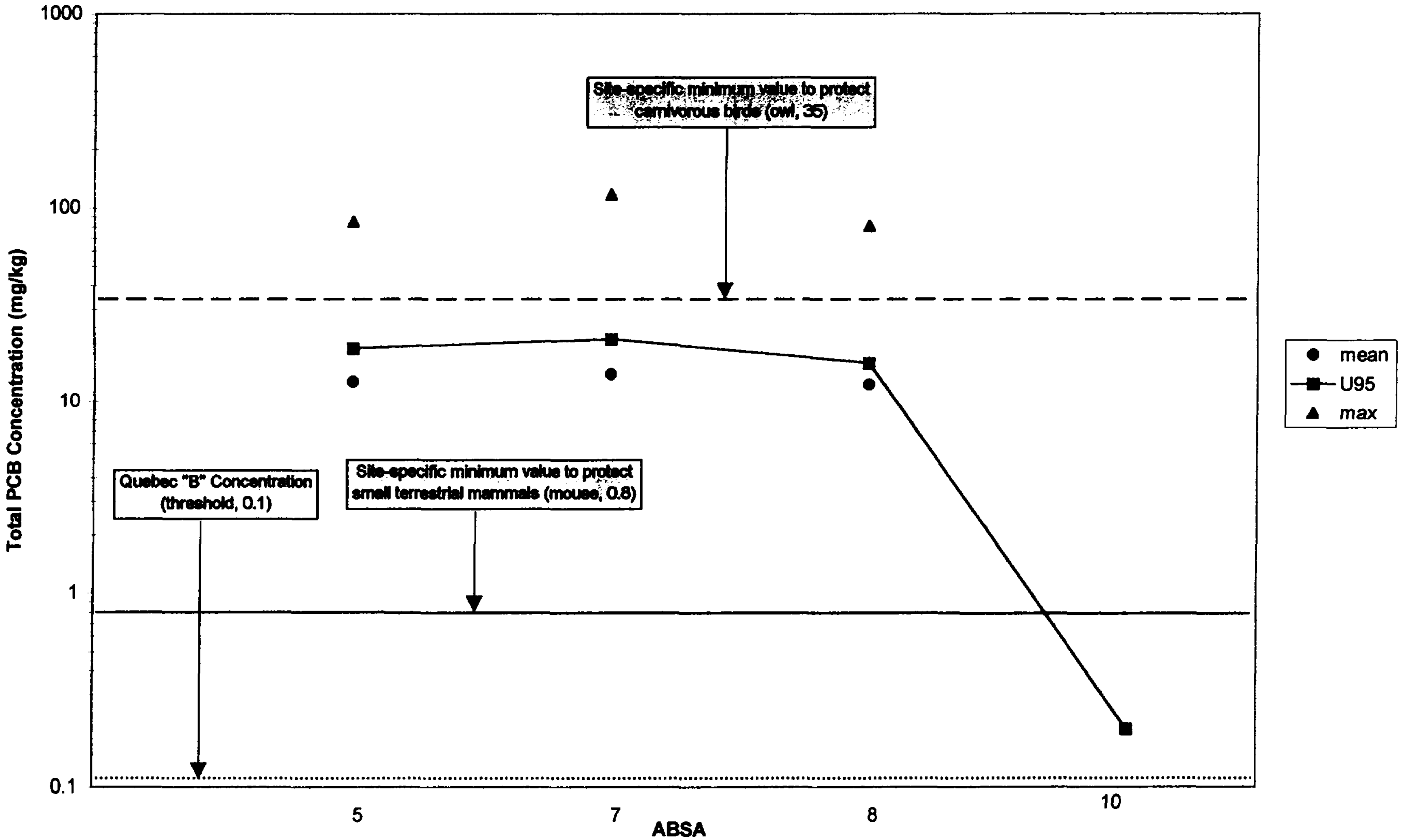
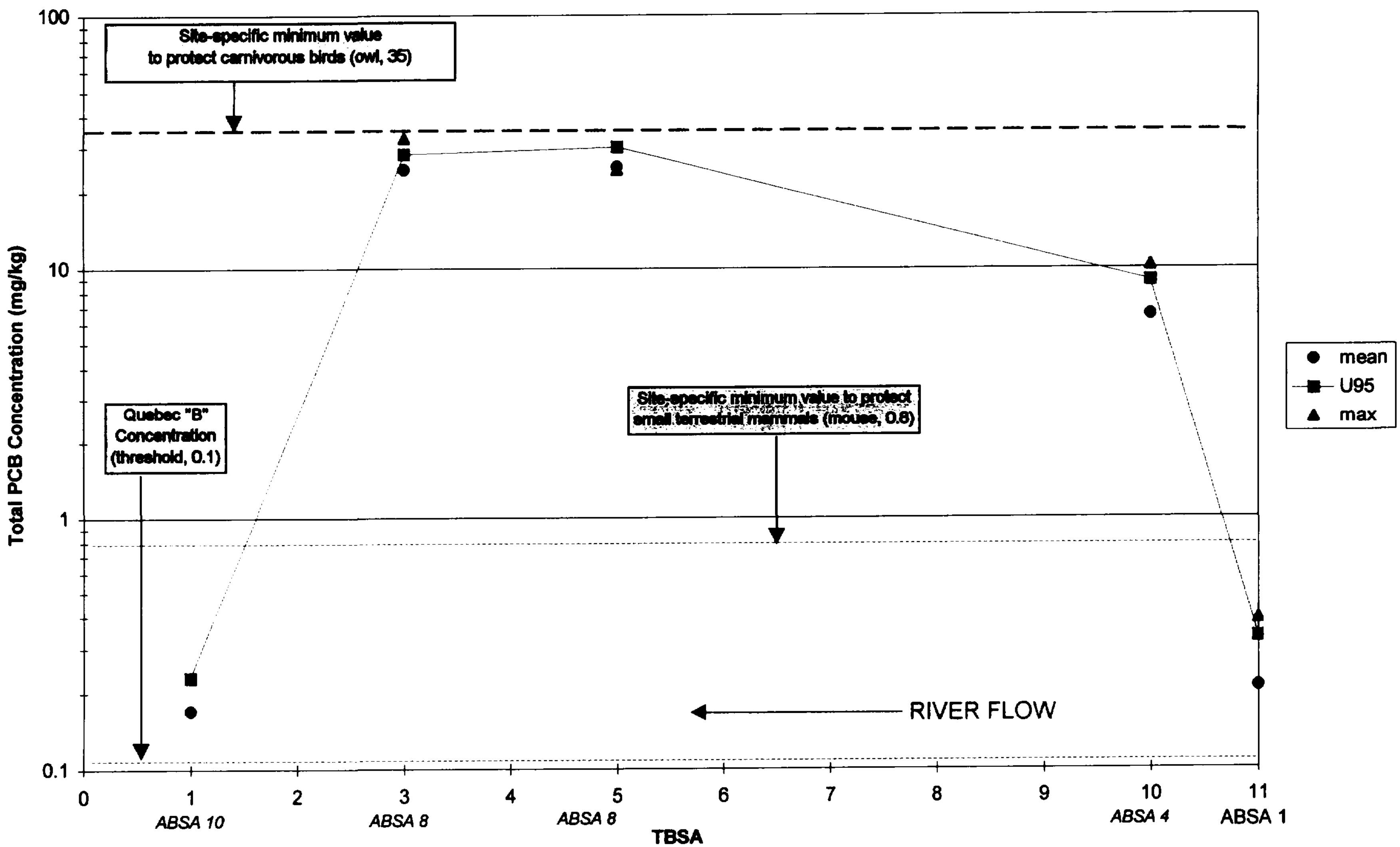


Figure 5-4
Total PCB Concentration
API/PC/KR Surface Soil



5.1.4 Risks from PCBs in Food Items (Ingestion)

Risks to consumers of onsite plants and animals are expected to be highly variable. No site-specific PCB values are available for determining PCB concentrations in site plants, but PCBs are generally believed to bioaccumulate in plants to a much lower degree that they do in animals. However, PCB concentrations in site plants can, based on limited literature soil-to-plant uptake values, be a concern because onsite soil PCB concentrations are sufficiently elevated in some areas to suggest elevated PCB concentrations in exposed plants, especially riparian or semi-aquatic plants that grow in aquatic environments or wet soils. The uncertainties associated with this pathway are discussed in a following section on uncertainties.

Table 5-1 summarizes the results of the PCB food web model for terrestrial species, based on the ingestion pathway. **Table 5-2** presents estimated threshold (or protective) concentrations for PCBs in surface soil for mouse, robin, great horned owl, and red fox. These thresholds are derived from literature-based toxicity and dietary data and site-specific PCB concentrations in surface soil. Of these, only songbirds, represented by the robin, and possibly small omnivorous rodents, appear to have potential to be substantially exposed to PCBs through ingestion of contaminated plants. The risks to these types of biota are based on comparisons of calculated soil thresholds to measured PCB concentrations in soil, and are the result of (1) the elevated site-wide PCB concentrations in surface soil, (2) the relatively high proportion of plants in diet, (3) the relatively low dietary LOAEC for mice and especially songbirds exposed to PCBs, and (4) the estimated PCB concentration in plants. Again, the latter is associated with considerable uncertainty because of the wide variability in PCB uptake by plants. As stated previously, uptake by aquatic or semi-aquatic plants is expected to be greater than for plants in dry environments. Also, muskrats also could potentially be exposed through incidental ingestion of contaminated sediments on the roots and stems of semi-aquatic and riparian plants. There is substantial uncertainty associated with the estimated onsite plant PCB concentrations, however, and estimated risks, based on ingestion of plants, should therefore be viewed with caution.

Risks to consumers of PCB-contaminated animals are also expected to vary from insignificant to serious, depending on consumer and prey species as well as season and location. For example, of terrestrial consumers evaluated (i.e., robin, white-footed/deer mouse, great horned owl, red fox, and bald eagle), all except the great horned owl may be at some level of risk from PCB contamination via ingestion of food items.

The types of consumers most likely to be at serious risk at this site are consumers of aquatic prey. Aquatic biota within the API/PC/KR, especially carp, are much more seriously contaminated with PCBs than are terrestrial biota that are likely to serve as prey for piscivorous predators such as mink. Mink are at most risk from PCB contamination through ingestion of prey because they

- consume large amounts fish that can be highly contaminated,
- are likely to obtain most or all prey within the site boundaries, and
- are the most sensitive to PCBs of all animals studied to date (Eisler 1986).

The maximum allowable tissue concentration for dietary items of mink is 0.22 mg/kg, based on the LOAECs and estimated NOAEC from the four studies described previously. That is, mink are expected to be adequately protected if the average PCB concentrations of all prey items contain less than 0.22 mg PCB/kg prey. **Appendix C** presents the likely prey of mink, which is expected to vary spatially and temporally. **Appendix C** also presents the recommended maximum allowable tissue concentration for dietary items for mink (0.64 mg/kg) recommended by Aulerich et al. in Eisler (1986, 0.1 mg/kg fresh weight diet).

U95 PCB concentrations in fish collected from ABSAs 3-9 (the primary potential impact areas) range from 0.90 (sucker) to 16.1 mg/kg (carp). Carp collected just downstream of the site, below Allegan Dam, contained up to 36 mg/kg PCBs. Carp are of special concern to mink protection because they may be preferentially consumed by mink. This is based on the following:

- carp contained the highest PCB concentrations of all sampled aquatic biota, including other fish species

- carp are found throughout the site in shallow areas that are most accessible to mink

- carp carcasses are commonly found along the river banks

- carp are long-lived, thereby increasing exposure duration and PCB bioaccumulation

- carp are extremely abundant in several areas of the Kalamazoo River

- carp are slow-moving and probably easier to catch than bass or other fish species

The latter two factors contribute to the likelihood that carp will be preferentially consumed by larger piscivorous predators such as mink. Fish consumption by certain individual mink, or by most mink during certain seasons, is likely to be supplemented by consumption of mammals, birds, amphibians, reptiles, and invertebrates (e.g., crayfish). Of these, consumption of muskrat, mice, and crayfish probably occur most regularly. Site-specific data are unavailable to assess PCB contamination in crayfish, but PCB concentrations in crayfish are expected to be elevated because of direct contact with PCB-contaminated surface water and especially streambed sediments and porewater. Bioaccumulation of PCBs in other freshwater invertebrates (e.g., snail, amphipod) and saltwater crustaceans (e.g., grass shrimp, blue crab) does not differ markedly from that of freshwater and marine fish (EPA 1980). Crayfish are, therefore, likely to be a significant source of PCBs to consumers such a mink.

Muskrat and mice collected from the API/PC/KR reveal moderate to relatively low (respectively) whole body PCB concentrations compared to carp. Maximum whole body total PCBs onsite range from 0.28 to 0.45 mg/kg in mice and up to 8.4 mg/kg in muskrat. These potential prey items are, therefore, expected to contribute low (mice) to moderate (muskrat) levels of PCBs to mink diet. Consumption of muskrat by mink could contribute to adverse effects because in some areas whole body PCB concentrations in muskrat exceed the range of dietary LOAECs (0.25-2.0 mg/kg). However, muskrat are unlikely to make up a large portion of mink diet throughout the year, and consumption of carp is a greater concern. Muskrats are most likely to be consumed during the winter when fish and crayfish are not as readily available. Consumption of mice by mink is not a major concern because mean whole body PCB concentrations in sampled mice remained well below the range of dietary LOAECs for mink

Fish contamination is directly related to surface water PCB concentrations, and piscivorous avian predators such as bald eagles are likely to be exposed to PCBs primarily through ingestion of aquatic prey. The minimum recommended threshold (not to exceed) PCB dose for birds of prey is 0.36 mg PCB/kg BW per day. The calculated dose for bald eagles, based on the food web model and on input parameters presented in *Appendix C,* is 0.61 mg PCB/kg BW per day. Bald eagles with a diet similar to that presented in *Appendix C* can therefore be adversely affected by PCB contamination. Because this potential risk is based on a diet of 77 percent fish, risks may be minimized where diets include a smaller proportion of fish or where fish are less contaminated than the values used in the food web model.

PCB concentrations in the Kalamazoo River and Portage Creek surface water and streambed sediment clearly pose substantial risks to aquatic biota, including aquatic

Table 5-1
Summary of the API/PC/KR
PCB Food Web Model, Terrestrial Species [1]

Receptor	Estimated Average Potential Daily Dose [1] (mg/kg/d)	Lowest Observed Adverse Effect Concentration (LOAEC)[2] (target species, mg/kg/d)	Observed or Estimated No Observed Adverse Effect Concentration (NOAEC)[3] (target species, mg/kg/d)	Recommended Dietary Threshold Value (mg/kg/d)
Muskrat	0.013	150 (500 mg/kg diet, 15% mortality, rat)	0.5 (rat, observed)	<0.005 (rat)
Mink	0.62	0.1 (0.69 mg/kg diet, reproductive effects, mink)	0.01 (0.069 mg/kg diet, estimated, mink)	<0.014
White-footed/ Deer Mouse	2.8	6.5 - 26.1 (25-100 mg/kg diet, reduced aestivation, white-footed mouse)	0.5 (rat, observed)	<0.005 (rat)
American Robin	13.9	6.0 (5.0 mg/kg diet, reproductive impairment, chicken)	0.6 (estimated)	<3.6 (birds)
Great Horned Owl	0.13	3.3 (33 mg/kg diet, reduced sperm production, American kestrel)	0.3 (observed)	<0.30 (birds)
Red Fox	0.70	2.6 (estimated from NOAEC, 16 mg/kg diet)	0.26 (dog, observed)	<0.0025 (dog)
Bald Eagle	0.61	4.0 (33 mg/kg diet, reduced sperm production, American kestrel)	0.4 (estimated)	<0.36 (birds)

[1] $\frac{[\text{sum (PCB Conc prey * DF prey)}] * \text{IR} * \text{SFF}}{\text{BW}}$

[2] References for LOAECs/LOAECs from Table C-1

[3] estimated NOAECs from LOAEC/10

TABLE 5-2
Calculation of Threshold Values for PCBs in Surface Soil for Representative Terrestrial Food Web Species

SPECIES - LOCATION (U95 SS PCB Conc, mg/kg)	LOAEC (mg PCB/ kg diet)	NOAEC [1] (mg PCB/ kg diet)	DIETARY ITEM	DIETARY FRACTION (DF)	MEAN FOOD ITEM BAF	PCB CONC FOOD ITEM [2] (mg/kg)	DIETARY PCB INTAKE (PCB CONC FOOD*DF, mg/kg)	SPECIES-SPECIFIC SOIL THRESHOLD [3] (mg PCB/ kg SS)
White-footed/ Deer Mouse								
TBSA 10	25	0.5	ter PLANTS	0.44	1.3	11.6	5.1	
(8.9)			ter INVERTS	0.56	0.09	0.8	0.45	0.8-40
							TOTAL: 5.5	
TBSA 3	25	0.5	ter PLANTS	0.44	1.3	36.8	16.2	0.8-40
(28.3)			ter INVERTS	0.56	0.09	2.5	1.4	
							TOTAL: 17.6	
TBSA5	25	0.5	ter PLANTS	0.44	1.3	39.3	17.3	0.8-40
(30.2)			ter INVERTS	0.56	0.09	2.7	1.5	
							TOTAL: 18.8	
TBSA1	25	0.5	ter PLANTS	0.44	1.3	0.3	0.13	0.8-40
(0.23)			ter INVERTS	0.56	0.09	0.02	0.012	
							TOTAL: 0.14	
Robin	5	0.5	ter PLANTS	0.49	1.3	24.2	11.9	
Site-wide*			ter INVERTS	0.51	0.09	1.7	0.9	
(16.9)							TOTAL: 12.8	0.7-7
Great Horned Owl	33	3.3	ter INVERTS	0.2	0.09	1.7	0.34	
Site-wide			HERPS	0.2	ND	3.9	0.8	
(16.9)			BIRDS	0.2	0.08	1.5	0.3	
			MAMMALS	0.4	0.02	0.37	0.15	
							TOTAL: 1.6	35-319
Red Fox	16	1.6	ter PLANTS	0.11	1.3	24.2	2.7	
Site-wide			ter INVERTS	0.04	0.09	1.7	0.07	
(16.9)	(estimated		HERPS	0.08	ND	3.9	0.31	
	from		BIRDS	0.19	0.08	1.5	0.29	
	NOAEC*10)		MAMMALS	0.58	0.02	0.37	0.21	
							TOTAL: 3.6	8-75

TABLE 5-2 (cont.)
Calculation of Threshold Values for PCBs in Surface Soil for Representative Terrestrial Food Web Species

[1] Based on Low est Observed Adverse Effects Concentration (LOAEC) / 10, except for R3ed Fox (reported NOAEC)
[2] (1) ter invert = TBSA-specific or site-wide average of U95 SS PCB concentration * site-wide average of maximum PCB concentration in earthworms
(2) ter plants = TBSA-specific or site-wide average of U95 SS PCB concentration * plant BAF
(3) mammal = site-wide average of maximum PCB concentration measured in white-footed/deer mice
(4) herps = average of maximum PCB Conc measured in all fish and deer mice
(5) birds = site-wide average of U95 SS PCB concentration * BAF for birds
[3] Threshold = LOAEC or NOAEC/Total Dietary PCB Intake * PCB Conc SS
* Sitewide averages based on mean of U95 values from TBSAs 1, 3, 5, and 10

invertebrates and fish (**Table 5-3**). An important goal for the API/PC/KR is re-establishment of an anadromous salmonid fishery. Toxicity data indicate that salmonids are likely to be among the most sensitive aquatic biota to PCBs (EPA 1980). The re-establishment of a self-sustaining salmonid fishery must, therefore, consider PCB effects on salmonid eggs, larvae, and young as well as effects on adult salmonids and prey species consumed by salmonids. In general, early life stages of fish are more sensitive to contaminants than adults, and reproductive success depends on providing safe exposures for these life stages. Obviously, suitable spawning and rearing habitats must also be present if a self-reproducing fishery is to become established in the Kalamazoo River.

5.1.5 Site-wide Summary of Risks

Table 5-3 presents the estimated risks for all representative species of concern based on site-wide average exposures. For risks based on surface water exposure, the risk estimates consider only the direct potential toxicity to exposed receptors. Risks to aquatic biota resulting from bioaccumulation are not included. Risks to other biota are based on estimated PCB dose. **Table 5-3** presents the results of a simplified hazard quotient approach (e.g., exposure conc/effects conc) that presents risk in a very general manner for representative receptors.

These risks are based on averages of site-wide U95 (abiotic media and fish) or maximum (terrestrial biota) exposure concentrations across all locations. For most species or individuals, these risks probably substantially over-estimate actual risks in relatively clean areas. Similarly, these risks are probably greatly under-estimated for highly contaminated areas. Average risks are therefore unlikely to be highly useful for evaluating location-specific contamination.

5.2 Risks from Non-Chemical Stressors

The major non-chemical stressors contributing to biological impairment of the Kalamazoo River are disturbed aquatic and terrestrial habitats. Disturbances of aquatic habitat appear to be primarily caused by sediment inputs from upstream sources and from streambank erosion. Where such sedimentation includes deposition of fine grained materials, preferred habitat is lost for most desirable benthic macroinvertebrates. Spawning areas for many fish species would also be similarly affected where deposition of fine grained sediments predominates. Adults of certain fish species would also be affected by conditions that impaired the colonization,

Table 5-3
Summary of Risks to Ecological Receptors
Site-wide Overview Based on Toxicity to Host - (bioaccumulation risks not included)

Ecological Receptor Group or Target Species	Exposure Concentration Total PCBs (mean U95 SW)[1] (average estimated diet)	Observed or estimated NOAEC [2]	Hazard Quotient (Exp/Effect)	Ranked Risk [3]	Comments
Mink	0.62 mg/kg/d dietary dose	0.01 mg/kg/d dietary dose	62	1	Highly confident risk estimate because of extensive data - high risk from ingestion of PCB-contaminated fish, especially carp
American Robin	13.9 mg/kg/d dietary dose	0. 6 mg/kg/d dietary dose	23	2	Risks may be conservative because of uncertainty in PCB concentration in terrestrial vegetation
White-footed/ Deer Mouse	2.8 mg/kg/d dietary dose	0.5 mg/kg/d dietary dose	5.6	3	Risks may be conservative because of uncertainty in PCB concentration in terrestrial vegetation
Red Fox	0.70 mg/kg/d dietary dose	0.26 mg/kg/d rec. threshold	2.7	4	Risks may be conservative because of uncertainty in PCB concentration in terrestrial vegetation
Bald Eagle	0.61mg/kg/d dietary dose	0.4 mg/kg/d dietary dose	1.5	4	Risk primarily from consumption of PCB-contaminated fish - species regularly observed onsite - nesting confirmed onsite
Great Horned Owl	0.13 mg/kg/d dietary dose	0.3 mg/kg/d dietary dose	0.4	5	Primary prey are not likely to be highly contaminated with PCBs but long-term exposure can increase risk
Muskrat	0.013 mg/kg/d dietary dose	0.5 mg/kg/d dietary dose	0.03	6	Risks may be underestimated because PCB concentrations in aquatic vegetation are expected to be greater than those in terrestrial plants
Salmonid Fish	0.000043 ug/L surface water	0.014 ug/L surface water	<<1	7	Low toxicity risk based on mean of U95 SW PCB concentrations. Risks higher where SW PCB concentrations are higher. Bioaccumulation is major concern for food chain effects.
Smallmouth Bass	0.000043 ug/L surface water	0.014 ug/L surface water	<<1	7	Low toxicity risk based on mean of U95 SW PCB concentrations. Risks higher where SW PCB concentrations are higher. Bioaccumulation is major concern for food chain effects.
Aquatic Invertebrates	0.000043 ug/L surface water	0.014 ug/L surface water	<<1	7	Low toxicity risk based on mean of U95 SW PCB concentrations. Risks higher where SW PCB concentrations are higher. Bioaccumulation is major concern for food chain effects.
Sucker	0.000043 ug/L surface water	0.014 ug/L surface water	<<1	7	Low toxicity risk based on mean of U95 SW PCB concentrations. Risks higher where SW PCB concentrations are higher. Bioaccumulation is major concern for food chain effects.

Table 5-3
Summary of Risks to Ecological Receptors
Site-wide Overview Based on Toxicity to Host - (bioaccumulation risks not included)

Ecological Receptor Group or Target Species	Exposure Concentration Total PCBs (mean U95 SW)[1] (average estimated diet)	Observed or estimated NOAEC [2]	Hazard Quotient (Exp/Effect)	Ranked Risk [3]	Comments
Carp	0.000043 ug/L surface water	0.014 ug/L surface water	<<1	7	Low toxicity risk based on mean of U95 SW PCB concentrations. Risks higher where SW PCB concentrations are higher. Bioaccumulation is major concern.

1 Probably under-estimates exposure concentrations for some locations and species.
2 Criteria=chronic AWQC; Effects Concentrations include LOAEC, estimated NOAEC, and Chronic Values (Ref: Tables 4-8 and C-1)

survival, growth, and reproduction of prey species, including benthic macroinvertebrates. Finally, fine grained sediments are expected to be more toxic to aquatic life than large grained sediments because of increased sorption of PCBs on fine grained materials. Sedimentation in the Kalamazoo River is, therefore, a source of both physical (habitat disturbance) and chemical (PCB toxicity) stress on resident aquatic biota.

Terrestrial habitats are disturbed by the physical presence of PCB-contaminated surface soils and deposited sediments and the toxic conditions associated with these media precludes the maintenance of a diverse and healthy plant community in some cases. This in turn adversely affects animals that require sufficient food (herbivorous species) and cover (most all species) for survival and reproduction. Sensitive soil-dwelling animals, along with sensitive plant species, are not expected to inhabit areas where PCB contaminated media substantially replaces or covers native soils. The expected decrease in abundance and diversity of soil biota, including important microorganisms critical to nutrient recycling, can be due to both physical (displacement or covering of native soil) and chemical (toxicity) causes. As stated previously, PCB-contaminated streambank sediments/surface soils are also likely to contribute to impairment of the Kalamazoo River through erosion and runoff.

5.3 Risk Summary and Ecological Significance

Section 5.3.1 summarizes the risks for this site. The ecological significance of these risks are also included in this summary. The risk summary is followed (Section 5.3.2) by other observations or information that contributes to the weight-of-evidence presented in the ERA. This section provides support for the risk estimates summarized below.

5.3.1 Risk Summary

Table 5-3 presents the summary of risks for all representative ecological receptors based on dose (terrestrial receptors) or direct toxicity (aquatic receptors). **Figures 5-5** and **5-6** present total PCB concentrations in terrestrial biota and fish, respectively, for sampled locations. **Figures 5-7, 5-8, 5-9** presents mean, U95, and maximum whole body total PCB concentrations measured in suckers, smallmouth bass, and carp, respectively. These values are overlaid with the geometric mean of four dietary LOAECs and estimated NOAECs (LOAEC/10) determined for reproductive effects in mink. The mean of these two values, 0.22 mg/kg wet weight diet, serves as the best

Figure 5-5
Maximum Whole Body Total PCB Concentrations in Terrestrial Biota

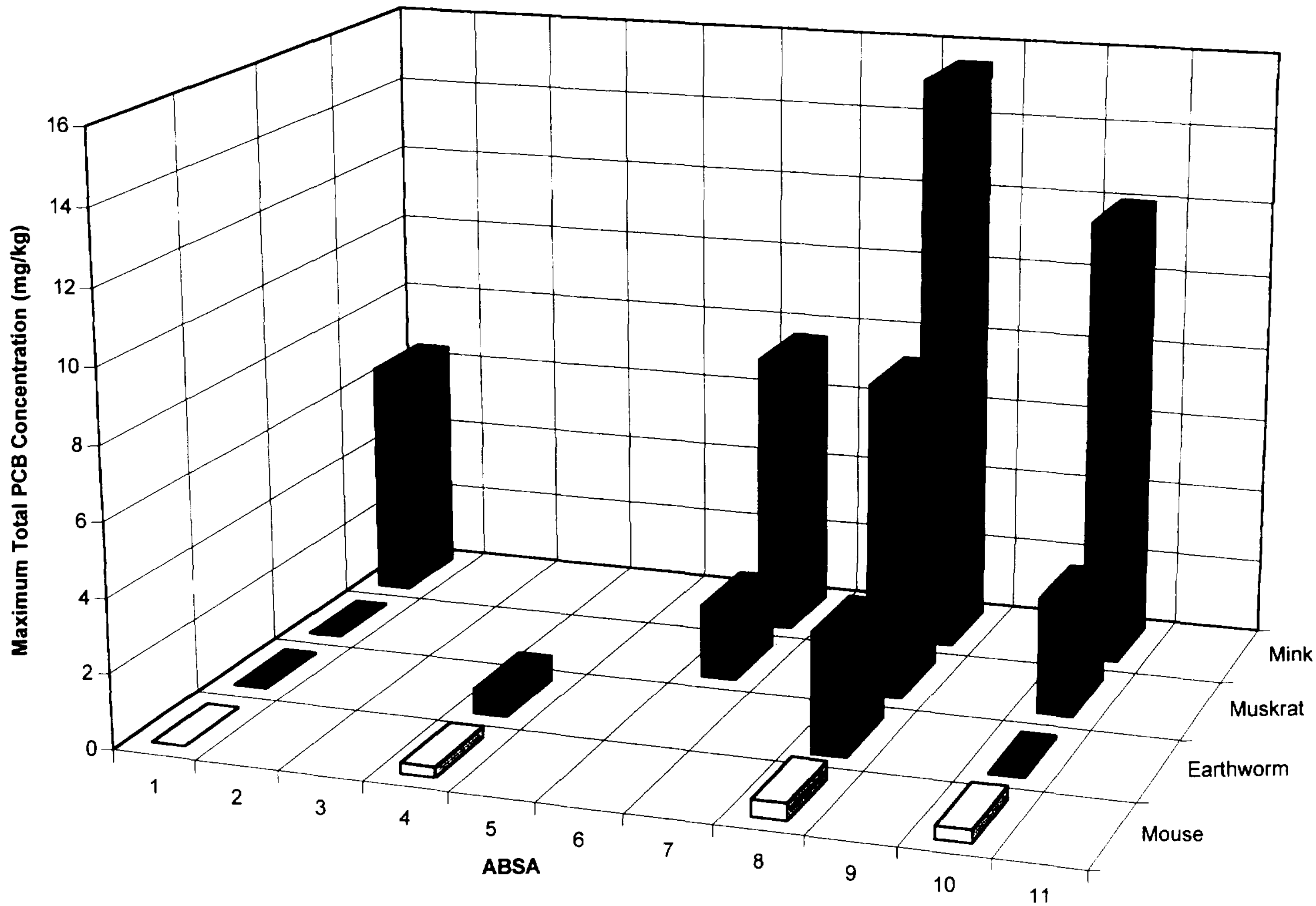


Figure 5-6
U95 Fish-Whole Body
Total PCB Concentrations

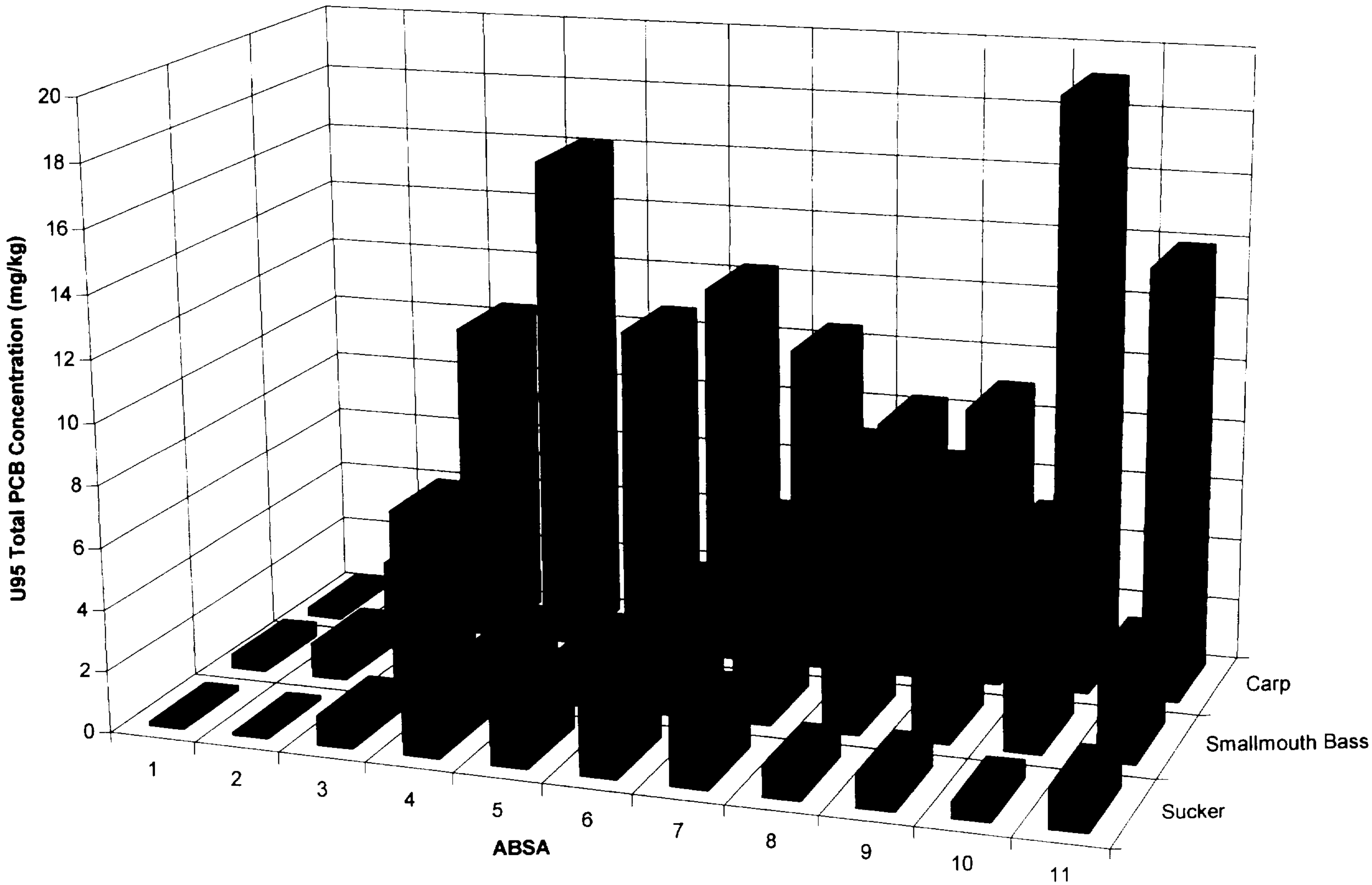


Figure 5-7
Smallmouth Bass-Whole Body
Total PCB Concentrations

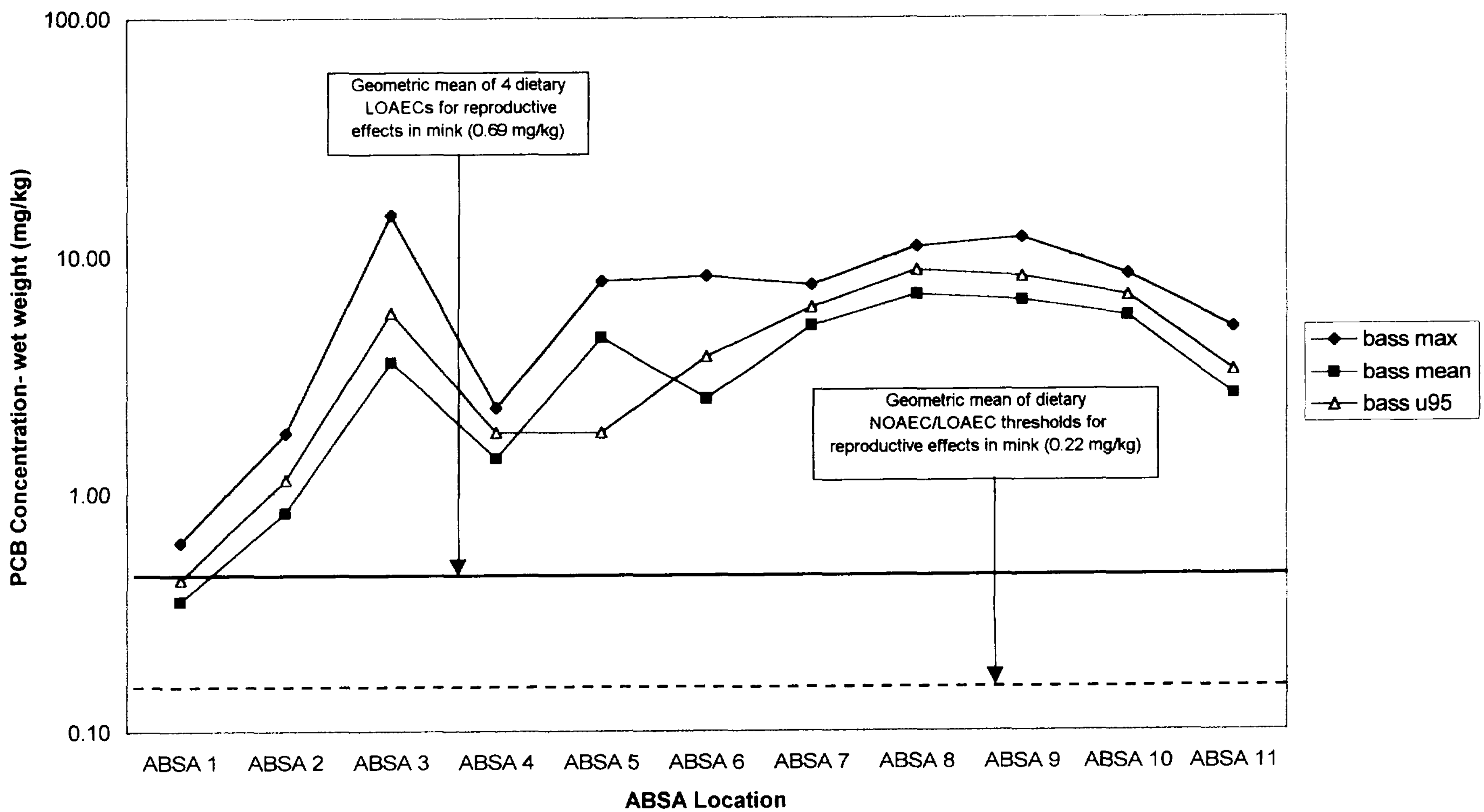


Figure 5-8
Common Carp-Whole Body
Total PCB Concentration

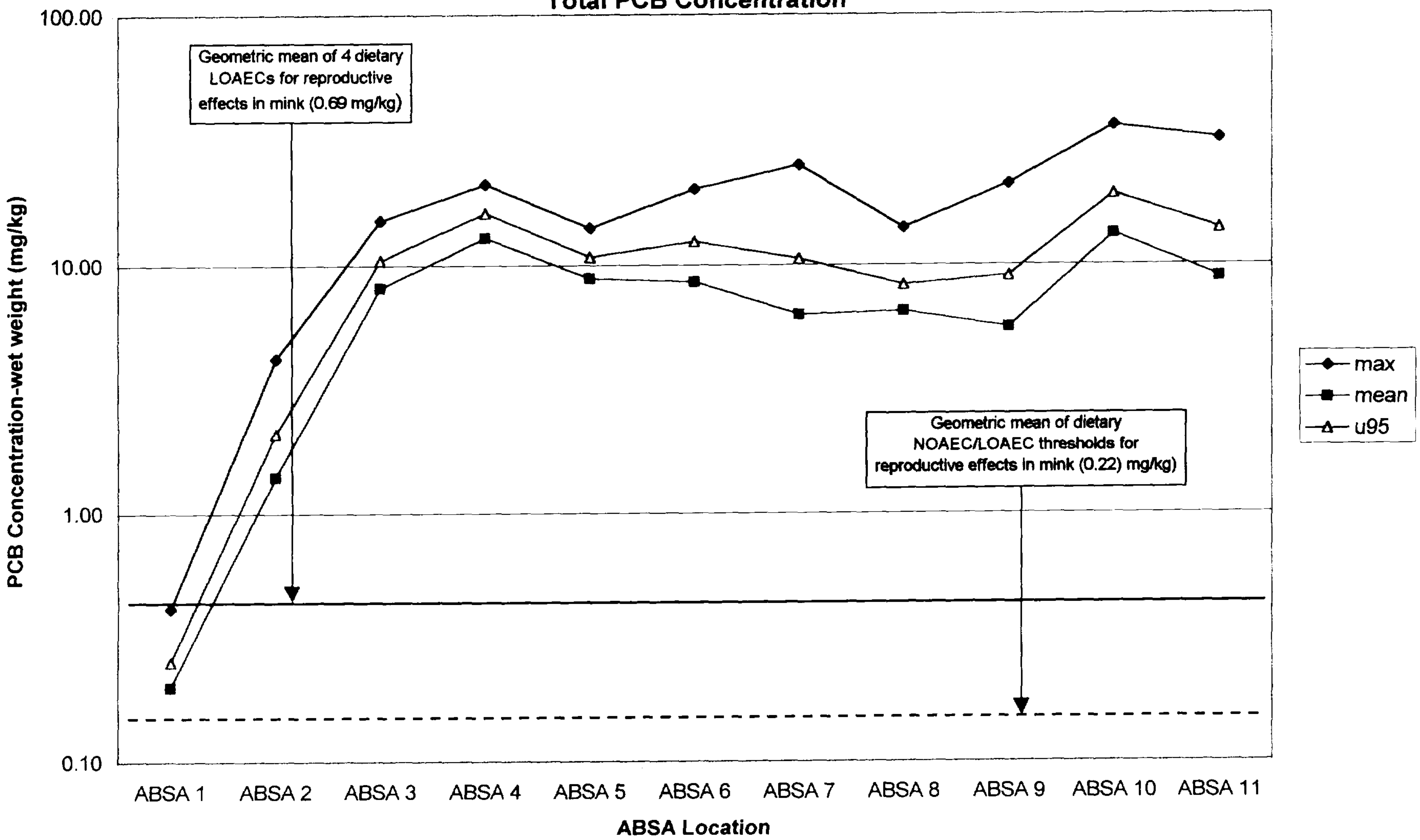
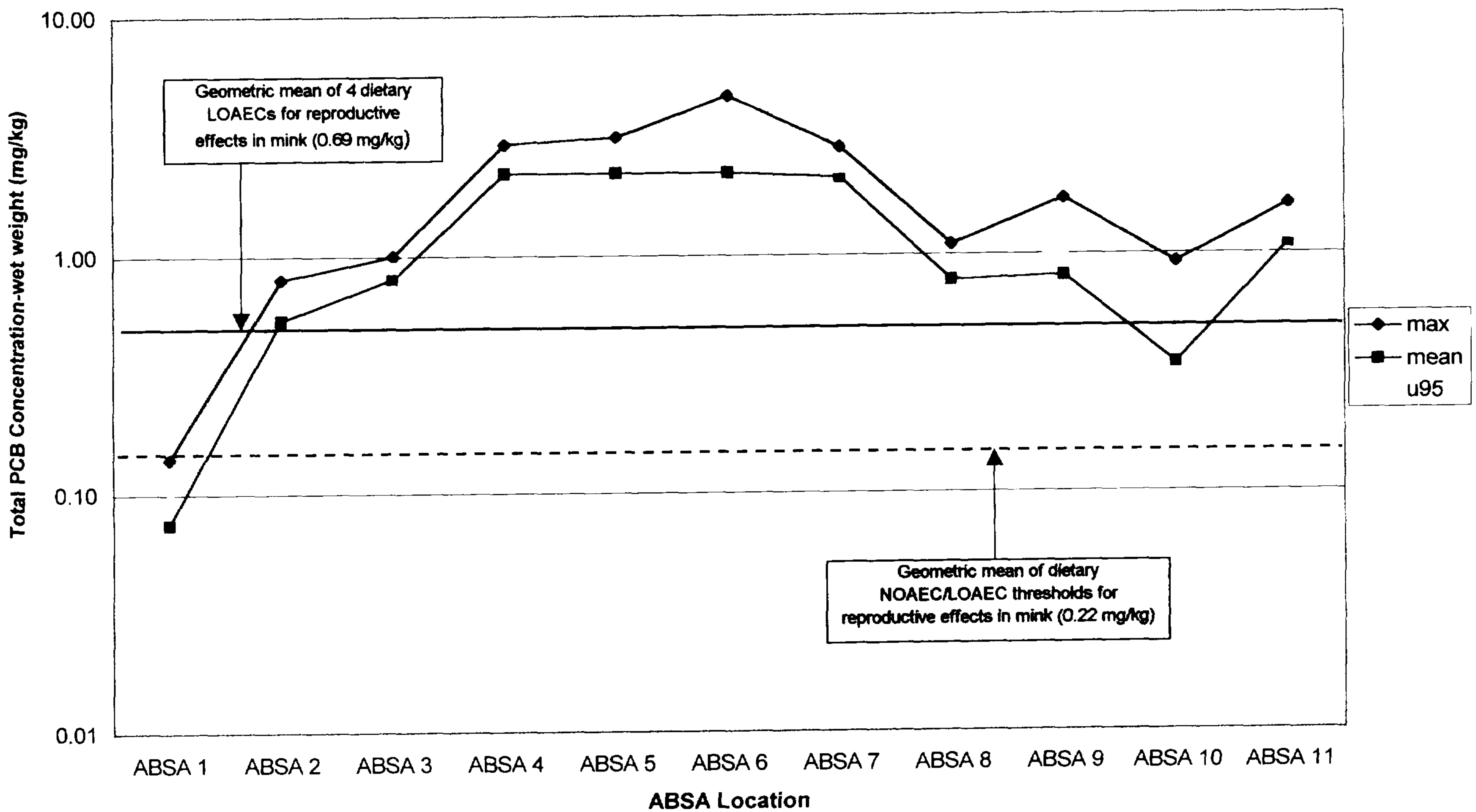


Figure 5-9
Sucker Species-Whole Body
Total PCB Concentrations



estimate for a "not to exceed" threshold to protect mink from reproductive effects. This figure depicts an important data source that allows for the conclusion that the fish-->mink pathway is the most critical pathway for ecological risks related to PCB contamination.

The risks from the site-wide representation presented in **Table 5-3** are considered in addition to the location-specific distribution and concentration of PCBs described in previous sections (e.g., **Table 4-5**) and presented in part of **Figures 5-5 and 5-6**. The data presented in **Figures 5-7, 5-8, 5-9** are also used to describe important risk-related information. Together this information is used to summarize risks in the following discussion.

- Most aquatic biota such as invertebrates and fish are unlikely to be adversely affected by direct contact with and ingestion of surface water because of relatively low PCB toxicity to most aquatic biota. Adverse effects may be exhibited by sensitive aquatic biota such as some species of aquatic plants, but such effects are likely to be spatially and temporally limited.

- PCB contamination of surface water and streambed sediment is likely to indirectly but potentially greatly affect sensitive piscivorous predators, such as mink, through consumption of PCB-contaminated prey, especially fish.

  — Impaired reproduction of mink and ultimately decreases in mink populations are the most likely effects of PCB contamination in aquatic prey. Henry, et al. (1998) demonstrated that concentrations of PCBs in smallmouth bass from a remote lake in the Upper Pennisula of Michigan were of concern to mink populations, even with the low levels of PCBs in fish tissue from this lake.

  — Other piscivorous predators, such as bald eagles, may be at risk if fish are the predominant prey item consumed and if foraging takes place mostly within contaminated aquatic areas. Field investigations of bald eagles by U.S. Fish and Wildlife suggest there has been a loss of reproductive capacity and decrease in the populations of bald eagles within the site boundaries..

- Terrestrial and semi-aquatic biota may be at risk from PCB-contaminated floodplain sediment and surface soil, depending on life history (e.g., foraging behavior, diet, mobility) and sensitivity to PCBs. Such risk are in general considered to be low.

  — Carnivorous terrestrial species (represented by the red fox) are unlikely to be at significant risk unless foraging is concentrated in riparian areas with contaminated floodplain sediment and diet consists of prey that (1) reside in PCB-contaminated areas, and (2) have taken up substantial amounts of PCBs.

— Omnivorous terrestrial species (represented by mice) are also unlikely to be at significant risk unless they reside in the most contaminated areas. PCB uptake in mice appears to be low.

— Omnivorous birds (represented by the robin) that consume a substantial amount of vegetation, would be at significant risk only if PCB uptake in plants approached the predicted uptake rate used in the ERA. The predicted uptake rate for terrestrial plants in dry environments is believed to be over-estimated to some extent. Consumption of terrestrial invertebrates such as earthworms is expected to contribute more to total PCB intake than ingestion of plants. Diets high in contaminated invertebrates would increase risks for omnivorous birds.

— Semi-aquatic herbivorous mammals (represented by muskrat) may be at risk from PCB contamination because estimated dietary doses exceed recommended threshold values for rats. This conclusion is based on the assumption that laboratory rats and muskrats are equally sensitive to PCBs via ingestion. Muskrats contaminated with PCBs may also cause adverse effects to muskrat predators because some muskrats contain PCBs in excess of recommended dietary limits for PCB-sensitive predators such as mink.

5.3.2 Other Supporting Information

This section presents a compilation of qualitative findings, anecdotal information, and observations thatsupport the risk estimates presented in this ERA. This information by itself cannot be used to derive risks or characterize the site in any particular way. However, the following information is considered useful to add to the weight-of-evidence presented in this ERA. The following is therefore intended to support the conclusions and assumptions presented and discussed in this ERA.

- Young-of-year smallmouth bass (1+ years) had PCBs greater than >3 ppm

- mink trapping success was inversely correlated to level of PCB contamination at TBSAs
  - habitats were similar at all locations
  - equal trapping time was expended at each location

- maximum concentration of total PCBs in mink liver was 52 mg/kg

  - this value represents one of the highest observed at any location in the country (Charters 1996)

- bald eagles at the Allegan State Game Area have had very poor reproductive success (Best 1999)
  - since monitoring began in 1960, two fledged young have been produced in 15 breeding attempts (0.13 fledged young per occupied breeding area--0.7 is indicative of stable population) (Best 1999)

- great horned owl eggs from the Allegan State Game Area contained 89 mg/kg and brain contained 90.8 mg/kg total PCBs

- redtail hawk eggs from the Allegan State Game Area contained up to 27.1 mg/kg total PCBs

- mute swan eggs from the Allegan State Game Area contained up to 1.6 mg/kg total PCBs

- wood duck eggs from the Allegan State Game Area contained up to 0.45 mg/kg total PCBs

- previously observed great blue heron colony alongside Kalamazoo River is gone

- regional bald eagle sightings reported to MDNR have all been from alongside the Kalamazoo River within the site boundaries
  - this supports the use of 1.0 for a SFF for bald eagles

- non-normalized average BSAFs for other sites in the Great Lakes region consistently range from a little less than 1 to about 2
  - average BSAFs for this ERA range from 0.28 to 1.9

5.4 Uncertainty Evaluation - Risk Characterization

By definition, uncertainties in risk characterization are influenced by uncertainties in exposure assessment and effects assessment. Uncertainties in exposure assessment are considered to be minimized by the adequate sampling and analysis of surface water, streambed sediment, floodplain sediment, surface soil, and biota.

Descriptions of the magnitude and distribution of PCBs within the API/PC/KR are considered to be representative of current conditions.

Effects data can also contribute to overall uncertainty in risk characterization. Science and scientific investigations can not prove any hypothesis beyond doubt. The scientific method is instead based on stating hypotheses, testing these hypotheses, and either accepting or rejecting the hypotheses based on the weight-of-evidence provided by test data. Cause and effect relationships can be inferred, and evidence can support hypotheses, but cause and effect relationships can rarely be proven.

In this ERA, the primary null hypothesis is that the Kalamazoo River and associated aquatic and riparian habitats have not been and are not being adversely affected by PCBs and related physical stressors. These stressors are assumed to have originated primarily from past industrial activities along the Kalamazoo River. This null hypothesis is tested by using a weight-of-evidence approach that provides support for either rejection or acceptance of the proposed hypotheses. No data are conclusive. Site-specific biological and chemical data are subject to concerns of representativeness and availability and the sensitivity of sampled species used to derive such data. Toxicity data that are not site specific may not be totally applicable to the site being investigated. There are concerns about laboratory-to-field extrapolation of effects data. Taxa-to-taxa extrapolations are a concern as well. All effects data are, therefore, subject to some degree of uncertainty. Confidence in the ability of selected effects data to assess potential for ecological risks varies for each data value selected.

This ERA presents effects data in the risk characterization phase that can contribute to the weight-of-evidence approach used to assess potential for ecological risks. While each and every effects data value used in this and every other ERA is associated with some degree of uncertainty, it is the general trend described by the comparisons between exposure concentrations and effects concentrations, and the overall confidence in such comparisons, that are most important.

Another potential source of uncertainty is the lack of extensive biological or ecological surveys conducted over time to support this ecological risk assessment. The types of surveys needed to aid in the determination of cause and effect relationships are highly dependent on data quality and data quantity. For example, historical data on fish and furbearer populations could be used to evaluate population- level effects over time that might be associated with PCB contamination or other sources of ecological stress. Such data, however, are not currently available. Still, observations based on recent field work can be used to qualitatively evaluate evidence of adverse impacts.

For example, trapping success of mink appears to be associated with PCB contamination in sediment and fish. While equal trapping effort was expended at all locations, trapping success was substantially greater within the reference areas upstream of the API/PC/KR. Of the 10 mink collected for tissue analyses, five (50 percent of total) were taken from the upstream reference area (ABSA 1). Of the remaining five mink, one was taken from ABSA 6 upstream of Otsego City Dam, two from TBSA 5 upstream of Trowbridge Dam, and two from ABSA 10 downstream of Allegan Dam.

Although data are insufficient for making conclusions relating cause and effect of possible population level effects on mink, it is noted that fish tissue PCB concentrations are elevated within and downstream of the API/PC/KR. In addition, fish tissue PCB concentrations are substantially lower in areas where mink trapping was highly successful. Finally, the risk characterization method itself can contribute to uncertainty. This type of uncertainty is minimized by not relying on a single exposure point concentration (e.g., mean or maximum value) or on a single effects concentration (e.g., AWQC or LC_{50}). The weight-of-evidence approach used here provides a more meaningful approach that minimizes the effects associated with the inherent uncertainty in any particular exposure or effects data value.

This ERA presents overwhelming evidence that, despite uncertainties identified in the ERA, two and possibly three of the four proposed null hypotheses introduced in Section 3.4 and presented below can be rejected with little reservation.

- The levels of PCBs in water, sediment, and biota are not sufficient to adversely affect the structure or function of the fish populations in the Kalamazoo River and Portage Creek System.

- The levels of PCBs in water, sediment, and biota are not sufficient to adversely affect the survival, growth, and reproduction of plant and animal aquatic receptors utilizing the Kalamazoo River and Portage Creek system.

- The levels of PCBs in water, sediment, and biota are not sufficient to adversely affect the survival, growth, and reproduction of mammalian receptors utilizing the Kalamazoo River and Portage Creek system.

- The levels of PCBs in water, sediment, and biota are not sufficient to adversely affect the survival, growth, and reproduction of avian receptors utilizing the Kalamazoo River and Portage Creek system.

The first hypothesis is *accepted* because there is no direct evidence that fish communities are being affected by PCB contamination. The impaired fish community

of Lake Allegan is comprised primarily of stunted and often malformed carp. The cause of these findings cannot be determined from the available data. It is noted, however, that PCBs cause a wasting syndrome in several mammalian species. There is insufficient evidence to determine if similar results are exhibited by fish.
The second hypothesis is *conditionally accepted/rejected*. This is based on the finding that at some locations the maximum detected surface water PCB concentration exceeds the lowest chronic value for freshwater fish, invertebrates, or aquatic plants.

The last two hypotheses are rejected because there is sufficient evidence that adverse effects may be experienced by mammalian and avian predators, especially those that consume fish.

In summary, the ecosystem associated with the API/PC/KR portion of the Kalamazoo River has been and is currently being adversely affected by PCBs originating from past industrial activities.

5.5 Remediation Issues

The Kalamazoo River and nearby riparian areas are currently being adversely affected by nonpoint sources of chemical contamination. It is expected that remediation of the most serious and most ubiquitous contaminants (i.e., PCBs) would result in remediation of other less serious contaminants that are not as uniformly distributed or are present at lower concentrations. For this reason, this preliminary discussion of remediation issues is focused on remediation of PCBs in aquatic and terrestrial media.

Instream and floodplain sediments, surface water, surface soil, and biota within the API/PC/KR are contaminated with PCBs. Contaminated groundwater may discharge to the Kalamazoo River and Portage Creek as well, but groundwater inputs have not been quantitatively evaluated. It is expected that the most critical current nonpoint source of PCBs to the Kalamazoo River and Portage Creek are erosion and runoff of contaminated streambank sediments/soils and release of PCBs from streambed sediments to surface water. Surface water within the API/PC/KR is probably also affected by upstream, offsite inputs of both contaminated surface water and contaminated sediments, but such inputs appear to be small compared to onsite sources (e.g., areas of former impoundments). Again, contaminated groundwater may contribute to elevations in surface water PCB concentrations during certain times of the year and in certain locations, depending on groundwater/surface water relationships. Fine grained instream sediments probably move downstream at a rate dependent on flow. During and immediately following storm events, fine grained sediments are likely to move downstream rapidly, eventually entering depositional areas within the API/PC/KR or Lake Michigan. Lake Michigan probably acts as a sediment trap for sediments that reach far downstream. Several areas of the API/PC/KR are likely to trap substantial amounts of fine grained sediment, and removal of fine grained sediment from these depositional areas is likely to decrease biological impairment by removing a primary source of toxicity and instream siltation.

Stabilizing streambank materials is also expected to decrease the potential chemical and physical effects of erosion. Surface water concentrations of PCBs are unlikely to return to safe levels without consideration of both streambank and streambed sediments. Siltation must be controlled if a diverse and healthy aquatic community is to be established in affected areas of the API/PC/KR. Removal and/or capping of streambank sediments contaminated with PCBs is necessary to prevent erosion and runoff which ultimately contaminates and physically degrades the river.

Finally, the use of a single site-wide cleanup value for sediments is supported by the dynamic nature of the sediment environment. A single protective value derived for the entire site assumes that conditions can and do change both seasonally and from year to year, while multiple values assumes stable conditions at each location where a separate cleanup value may be derived. Since sediments are unstable and are continuously moving into the aquatic environment and downstream, the use of multiple ABSA-specific or other location-specific cleanup values is unwarranted.

Table 5-4 presents an overview of remediation-related issues and proposed media-specific cleanup values for the API/PC/KR. Risk reduction measures and the probable outcomes of such measures, along with proposed media-specific cleanup values, are directly related to the ERA-related remediation goals and objectives presented previously. The complexity of the factors affecting biological impairment within the API/PC/KR preclude a simple formula for deriving quantitative chemical-specific and media-specific cleanup numbers in all cases. For each media type, the selection of indicator chemicals is appropriate. That is, remediation of the most critical chemical component within each media type (e.g., PCBs) is likely to result in remediation of the less critical chemical stressors as well. Total PCBs can, therefore, serve as indicator chemicals for remediation purposes.

For surface water, control of streambank erosion and runoff and elimination or decrease in streambed sediment volumes and/or PCB concentrations are most critical. For streambed and streambank sediment, substantial decreases in total PCBs are warranted because these media will continue to provide a toxicant source to the Kalamazoo River and Portage Creek, and resident aquatic and terrestrial biota. For surface soil. concentrations of PCBs need to be substantially reduced where such soils have potential to erode into aquatic environments.

The selection of the most appropriate methods for achieving remediation goals is not a risk assessment issue but is a risk management issue to be addressed in the feasibility study (FS) for this API/PC/KR. The application of cleanup values is also considered a risk management decision. This risk assessment derives and recommends single point threshold PCB concentrations ("cleanup values") for each media type. It is most appropriate for risk managers rather than risk assessors to decide how to best apply cleanup values recommended in the risk assessment.

5.5.1 Summary of Recommended Cleanup Values

Table 5-4 summarizes the proposed cleanup levels for various media for the Kalamazoo River Superfund Site.

- Surface water total PCB concentrations should not exceed 0.00038 ug/L to protect mink, the most sensitive of all animals tested to date.

- Streambed sediment total PCB concentrations should not exceed 0.12 mg/kg to protect mink, the most sensitive of all animals tested to date. If floodplain sediments are likely to erode into aquatic environments, they should be treated the same as streambed sediments unless there is evidence indicating different sorption/desorption properties for PCBs bound to terrestrial soil particles that enter aquatic environments. The Baseline Human Health and Ecological Risk Assessment for the Lower Fox River and Green Bay, Wisconsin (ThermoRetec 1999) identified a clean up level of 0.006 mg/kg for instream sediments. This value is significantly more restrictive than the value being recommended for the Kalamazoo River.

- Surface soil and in some cases floodplain sediment PCB concentrations should not exceed 0.7 mg/kg to protect omnivorous songbirds such as robins, the most sensitive omnivorous terrestrial species evaluated in this ERA. This value is more uncertain than the values presented for instream sediments and surface water because of uncertainties associated with PCB uptake in plants. This value would apply to floodplain sediments where erosion into aquatic environments are unlikely.

The cleanup values derived for both FP SED/SS and SED are very similar (less than 1 mg/kg in all cases) even though the values for SED and FP SED/SS were developed completely independently using entirely different approaches. This concurrence precludes the need to differentiate between SS, FP SED, and SED when conducting remediation activities.

TABLE 5-4
Summary of Remediation Issues Relating to Ecological Risk

CHEMICAL STRESSOR (media)	RISK REDUCTION MEASURES	PROBABLE OUTCOME	PROPOSED MEDIA-SPECIFIC CLEANUP GOALS (total PCBs)	
Total PCBs (SW) (SED) (FP SED) (SS)	Stabilize or remove floodplain and streambank materials, remove fine grained sediment from streambed	Reduction in surface water and streambed PCB concentrations, which is likely to result in decreased PCB bioavailability for aquatic biota. Aquatic biota provide the most critical source of PCBs to aquatic and terrestrial predators. Reduction of SW and SED PCB concentrations are likely to reduce PCB concentrations in fish and other aquatic biota. Mink and other consumers of aquatic biota should be adequately protected if PCBs in aquatic prey are reduced to safe levels. Protection of the most sensitive predators (mink) should provide adequate protection for all other biota exposed to PCBs in aquatic and semi-aquatic media.	SW: 0.00038 ug/L	Value based on average site-specific BAF for carp (583,000), and geometric mean dietary threshold for mink (0.22 mg/kg).
			SED: 0.12 mg/kg	Calculated value to allow IW PCB concentration to remain below SW threshold of 0.00038 ug/L. Based on mean site-specific partitioning between SED and SW (Kd, 302,000). SW threshold based on mean BAF for carp.
			0.12 mg/kg	Same value also derived using mean BSAF for carp (1.9) and fish tissue limit of 0.22 mg/kg to protect mink.
			FP SED: See SED	Values based on SED remediation goals assuming potential erosion into aquatic environments. If contact with aquatic system unlikely, FP SED should be treated same as SS.
			SS: 0.7 mg/kg	Calculated threshold value to protect omnivorous songbirds based on American robin. Value is more uncertain because of uncertainties in PCB uptake in terrestrial plants.

Section 6
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Appendices

Appendix A

A

Species of Concern. Table A-1 presents plant and animal species of special concern that may potentially occur in or near the API/PC/KR area.

Table A-1
Plant and Animal Species of Special Concern Potentially Occurring In or Near the API/PC/KR Area

Scientific Name	*Common Name*	*County*
Endangered Vertebrates		
Acipenser fulvescens	Lake Sturgeon	Allegan
Acris crepitans blanchardi	Blanchard's Cricket Frog	Kalamazoo, Allegan
Ambystoma opacum	Marbled Salamander	Allegan
Ardea herodias	Great Blue Heron	Kalamazoo, Allegan
Clemmys guttata	Spotted Turtle	Kalamazoo, Allegan
Clemmys insculpta	Wood Turtle	Allegan
Clonophis kirtlandii	Kirtland's Snake	Kalamazoo
Cryptotis parva	Least Shrew	Kalamazoo
Erimyzon oblongus	Creek Chubsucker	Kalamazoo
Gavia immer	Common Loon	Allegan
Haliaeetus leucocephalus	Bald Eagle	Allegan
Ictiobus niger	Black Buffalo	Allegan
Lanius ludovicianus migrans	Loggerhead Shrike	Allegan
Lepisosteus oculatus	Spotted Gar	Kalamazoo
Microtus ochrogaster	Prairie Vole	Kalamazoo
Microtus pinetorum	Woodland Vole	Kalamazoo, Allegan
Notropis anogenus	Pugnose Shiner	Kalamazoo
Notropis texanus	Weed Shiner	Kalamazoo, Allegan
Rallus elegans	King Rail	Allegan
Sistrurus catenatus catenatus	Massasauga	Kalamazoo, Allegan
Terrapene carolina carolina	Eastern Box Turtle	Kalamazoo, Allegan
Endangered Invertebrates		
Calephelis mutica	Swamp Metalmark	Kalamazoo
Cyclonaias tuberculata	Purple Wartyback	Allegan
Hesperia ottoe	Ottoe Skipper	Allegan

Table A-1
Plant and Animal Species of Special Concern Potentially Occurring In or Near the API/PC/KR Area

Scientific Name	*Common Name*	*County*
Incisalia irus	Frosted Elfin	Allegan
Lycaeides melissa samuelis	Karner Blue	Allegan
Neonympha mitchellii mitchellii	Mitchell's Satyr	Kalamazoo
Nicrophorus americanus	American Burying Beetle	Kalamazoo
Pygaruei Spraguei	Sprague's Pygarctia	Kalamazoo, Allegan
Speyeria idalia	Regal Fritillary	Kalamazoo
Stylurus laurae	Laurea Snaketail	Kalamazoo
Endangered Vascular Plant Communities		
Agalinis gattingeri	Gattinger's Gerardia	Kalamazoo
Amorpha canescens	Leadplant	Kalamazoo
Angelica venenosa	Hairy Angelica	Kalamazoo
Arabis missouriensis var deamii	Missouri Rock-Cress	Kalamazoo, Allegan
Aristida dichotoma	Shinner's Three-Awned-Grass	Kalamazoo
Aster sericeus	Western Silvery Aster	Kalamazoo
Astragalus canadensis	Canadian Milk-Vetch	Kalamazoo
Astragalus neglectus	Cooper's Milk-Vetch	Kalamazoo
Baptisia lactea	White False Indigo	Kalamazoo, Allegan
Baptisia leucophaea	Cream Wild Indigo	Kalamazoo
Berula erecta	Cut-Leaved Water-Parsnip	Kalamazoo, Allegan
Besseya bullii	Kitten-Tails	Kalamazoo
Cacalia plantaginea	Prairie Indian-Plantain	Kalamazoo
Calamagrostis stricta	Narrow-Leaved Reedgrass	Kalamazoo
Carex albolutescens	Greenish-White Sedge	Kalamazoo, Allegan
Carex festucacea	Fescue Sedge	Kalamazoo, Allegan
Carex frankii	Frank's Sedge	Kalamazoo
Carex oligocarpa	Eastern Few-Fruited Sedge	Kalamazoo
Carex seorsa	Sedge	Kalamazoo
Carex straminea	Straw Sedge	Kalamazoo

Table A-1
Plant and Animal Species of Special Concern Potentially Occurring In or Near the API/PC/KR Area

Scientific Name	*Common Name*	*County*
Carya laciniosa	Shellbark Hickory	Kalamazoo
Cirsium hillii	Hill's Thistle	Kalamazoo
Cirsium pitcheri	Pitcher's Thistle	Allegan
Coreopsis palmata	Prairie Coreopsis	Kalamazoo
Corydalis flavula	Yellow Fumewort	Kalamazoo
Cuscuta campestris	Field Dodder	Kalamazoo
Cuscuta pentagona	Dodder	Kalamazoo
Cuscuta polygonorum	Knotweed Dodder	Kalamazoo
Cyperus flavescens	Yellow Nut-Grass	Kalamazoo, Allegan
Cypripedium candidum	White Lady-Slipper	Kalamazoo
Diarrhena americana	Beak Grass	Kalamazoo
Draba reptans	Creeping Whitlow-Grass	Kalamazoo
Dryopteris Celsa	Log Fern	Kalamazoo
Echinodorus tenellus	Dwarf Burhead	Allegan
Eleocharis compressa	Flattened Spike-Rush	Kalamazoo
Eleocharis engelmannii	Engelmann's Spike-Rush	Kalamazoo, Allegan
Eleocharis melanocarpa	Black-Fruited Spike-Rush	Kalamazoo, Allegan
Eleocharis microcarpa	Small-Fruited Spike-Rush	Allegan
Eleocharis tricostata	Three-Ribbed Spike-Rush	Allegan
Eryngium yuccifolium	Rattlesnake-Master	Kalamazoo
Euphorbia commutata	Tinted Spurge	Allegan
Eupatorium sessilifolium	Upland Boneset	Kalamazoo
Filipendula rubra	Queen-of-the-Prairie	Kalamazoo
Fuirena squarrosa	Umbrella Grass	Kalamazoo, Allegan
Gentiana flavida	White Gentian	Kalamazoo
Gentiana puberulenta	Downy Gentian	Allegan
Geum triflorum	Prairie-Smoke	Allegan
Gillenia trifoliata	Bowman's Root	Kalamazoo

Table A-1
Plant and Animal Species of Special Concern Potentially Occurring In or Near the API/PC/KR Area

Scientific Name	Common Name	County
Glyceria acutiflora	Manna Grass	Kalamazoo
Gymnocladus dioicus	Kentucky Coffee Tree	Kalamazoo
Helianthus hirsutus	Whiskered Sunflower	Kalamazoo
Hemicarpha micrantha	Dwarf-Bulrush	Kalamazoo, Allegan
Hibiscus moscheutos	Swamp Rose Mallow	Allegan
Hybanthus concolor	Green Violet	Kalamazoo
Hydrastis canadensis	Goldenseal	Kalamazoo, Allegan
Hypericum gentianoides	St. John's Wort	Kalamazoo
Isoetes engelmannii	Appalachian Quillwort	Allegan
Isotria verticillata	Whorled Pogonia	Kalamazoo
Juncus biflorus	Two-Flowered Rush	Kalamazoo, Allegan
Juncus brachycarpus	Short-Fruited Rush	Allegan
Juncus scirpoides	Scirpus-Flowered Rush	Kalamazoo, Allegan
Juncus vaseyi	Vasey's Rush	Allegan
Kuhnia eupatorioides	False Boneset	Kalamazoo
Lechea minor	Least Pinweed	Kalamazoo
Lechea pulchella	Legget's Pinweed	Kalamazoo
Lechea stricta	Erect Pinweed	Kalamazoo
Lemna valdiviana	Pale Duckweed	Kalamazoo
Liatris punctata	Dotted Blazing Star	Kalamazoo
Lindernia anagallidea	False Pimpernel	Kalamazoo
Linum sulcatum	Furrowed Flax	Kalamazoo
Linum virginianum	Virginia Flax	Kalamazoo
Ludwigia alternifolia	Seedbox	Kalamazoo, Allegan
Lycopodium appressum	Fern	Kalamazoo, Allegan
Lygodium palmatum	Climbing Fern	Kalamazoo
Morus rubra	Red Mulberry	Kalamazoo
Muhlenbergia richardsonis	Mat Muhly	Kalamazoo

Table A-1
Plant and Animal Species of Special Concern Potentially Occurring In or Near the API/PC/KR Area

Scientific Name	*Common Name*	*County*
Nelumbo lutea	American Lotus	Kalamazoo
Panax quinquefolius	Ginseng	Kalamazoo, Allegan
Panicum leibergii	Leiberg's Panic-Grass	Kalamazoo
Panicum longifolium	Long-Leaved Panic Grass	Allegan
Platanthera ciliaris	Orange-Finged Orchid	Kalamazoo, Allegan
Poa Paludigena	Bog Bluegrass	Kalamazoo
Polygala cruciata	Cross-Leaved Milkwort	Kalamazoo, Allegan
Polygonum careyi	Carey's Smartweed	Allegan
Populus heterophylla	Swamp Cottonwood	Kalamazoo
Potamogeton bicupulatus	Waterthread Pondweed	Allegan
Pycnanthemum verticillatum	Whorled Mountain-Mint	Allegan
Querus alba	White Oak	Allegan
Rhexia mariana var mariana	Maryland Meadow-Beauty	Allegan
Rhexia virginica	Meadow-Beauty	Kalamazoo, Allegan
Rhynchospora macrostachya	Tall Beak-Bush	Kalamazoo, Allegan
Rosa setigera	Prairie Rose	Kalamazoo
Rotala ramosior	Tooth-Cup	Kalamazoo, Allegan
Rudbeckia sullivantii	Showy Coneflower	Kalamazoo, Allegan
Sabatia angularis	Rose-Pink	Kalamazoo
Scirpus hallii	Hall's Bulrush	Allegan
Scirpus torreyi	Torrey's Bulrush	Allegan
Scleria reticularis	Netted Nut-Rush	Allegan
Scleria triglomerata	Tall Nut-Rush	Kalamazoo, Allegan
Scutellaria elliptica	Hairy Skullcap	Kalamazoo
Silene stellata	Starry Campion	Kalamazoo
Silphium intergrifolium	Rosinweed	Kalamazoo
Silphium laciniatum	Compass-Plant	Kalamazoo
Silphium perfoliatum	Cup-Plant	Kalamazoo

Table A-1
Plant and Animal Species of Special Concern Potentially Occurring In or Near the API/PC/KR Area

Scientific Name	*Common Name*	*County*
Sisyrinchium atlanticum	Atlantic Blue-Eyed Grass	Allegan
Smilax herbacea	Smooth Carrion-Flower	Kalamazoo
Spiranthes ovalis	Lesser Ladies'-Tresses	Kalamazoo
Sporobolus heterolepis	Prairie Dropseed	Kalamazoo, Allegan
Stellaria crassifolia	Fleshy Stitchwort	Kalamazoo
Trichostema dichotomum	Bastard Pennyroyal	Kalamazoo, Allegan
Trillium sessile	Toadshade	Kalamazoo
Triphora trianthrophora	Three-Birds Orchid	Kalamazoo
Utricularia subulata	Zigzag Bladderwort	Allegan
Valeriana ciliata	Edible Valerian	Kalamazoo
Valerianella chenopodiifolia	Goosefoot Corn-Salad	Kalamazoo
Viola pedatifida	Prairie Birdfoot Violet	Kalamazoo
Zizania aquatica var aquatica	Wild Rice	Kalamazoo

Table A-2
Plant Species Potentially Occurring In or Near the API/RI/KR Area

Family	*Species*	*Common Name*
Trees and Woody Plants		
Pinaceae	*Larix laricina*	Tamarack
	Pinus strobus	Eastern White Pine
	Pinus banksiana	Jack Pine
	Pinus resinosa	Red Pine
Annonaceae	*Asimina triloba*	Pawpaw
Magnoliaceae	*Liriodendron tulipifera*	Tuliptree
	Tilia americana	American Basswood
Salicaceae	*Populus deltoides*	Eastern Cottonwood
	Salix amygdaloides	Peachleaf Willow
	Salix nigrum	Black Willow
	Salix exigna	Sandbar Willow
	Salix discolor	Pussy Willow
Rosaceae	*Malus coronaria*	Wild Crab Apple
	Malus pumila	Common Apple
	Amelanchier arborea	Downy Serviceberry
	Prunus nigra	Canada Plum
	Prunus pensylvanica	Pin Cherry
	Prunus serotina	Black Cherry
	Prunus virginiana	Chokecherry
Fabaceae	*Gymnocladus dioicus*	Kentucky Coffeetree
	Gleditsia triacanthos	Honeylocust
	Cercis canadensis	Red Bud
Cornaceae	*Cornus alternifolia*	Alternate Leaf Dogwood
	Cornus florida	Flowering Dogwood
	Cornus stolonifera	Red Osier Dogwood
Hippocastanaceae	*Aesculus glabra*	Ohio Buckeye
Aceraceae	*Acer nigrum*	Black Maple
	Acer saccharum	Sugar Maple
	Acer rubrum	Red Maple
	Acer saccharinum	Silver Maple
	Acer negundo	Boxelder

Table A-2
Plant Species Potentially Occurring In or Near the API/RI/KR Area

Family	*Species*	*Common Name*
Juglandaceae	*Juglans cinerea*	Butternut
	Juglans nigra	Black Walnut
	Carya cordiformis	Bitternut Hickory
	Carya glabra	Pignut Hickory
	Carya laciniosa	Shellbark Hickory
	Carya ovata	Shagbark Hickory
Hamamelidaceae	*Hamamelis virginiana*	Witch-Hazel
Betulaceae	*Betula alleghaniensis*	Yellow Birch
	Betula papyrifera	White Birch
	Alnus rugosa	Speckled Alder
	Carpinus caroliniana	Blue Beech
	Ostrya virginiana	Hop-Hornbeam
Ulmaceae	*Celtis occidentalis*	Northern Hackberry
	Celtis tenuifolia	Dwarf Hackberry
	Ulmus americana	American Elm
	Ulmus thomasii	Rock Elm
	Ulmus rubra	Slippery Elm
Moraceae	*Morus rubra*	Red Mulberry
Fagaceae	*Castanea dentata*	American Chestnut
	Fagus grandifolia	Beech
	Quercus alba	White Oak
	Quercus bicolor	Swamp White Oak
	Quercus muehlenbergii	Chipkapin Oak
	Quercus prinoides	Dwarf Chinkapin Oak
	Quercus rubra	Red Oak
	Quercus velutina	Black Oak
	Quercus coccinea	Scarlet Oak
	Quercus ellipsoidalis	Northern Pin Oak
	Quercus palustris	Pin Oak
	Quercus imbricaria	Shingle Oak
Platanaceae	*Platanus occidentalis*	Sycamore

Table A-2
Plant Species Potentially Occurring In or Near the API/RI/KR Area

Family	*Species*	*Common Name*
Caprifoliaceae	*Viburnum lentago*	Nannyberry
Oleaceae	*Fraxinus americana*	White Ash
	Fraxinus nigra	Black Ash
	Fraxinus pennsylvanica	Red Ash
	Fraxinus quadrangulata	Blue Ash
Lauraceae	*Lindera benzoin*	Spicebush
Aquifoliaceae	*Ilex verticillata*	Winterberry
Anacardiaceae	*Toxicodendron vernix*	Poison Sumac
Grasses, Wildflowers, and Shrubs		
	Salix discolor	Pussy Willow
	Typha latifolia	Cattail
	Saururus cernuus	Lizard's Tail
	Rosa palustris	Swamp Rose
	Lythrum salicaria	Purple Loosestrife
	Iris versicolor	Blue Flag
	Pinguicula vulgaris	Common Butterwort
	Peltandra virginica	Arrow arum
	Lemna	Duckweed
	Polygonum amphibium	Smartweed
	Nymphaea odorata	Fragrant Water Lily
	Sambucus canadensis	Elderberry
	Nyssa sylvatica	Black Tupelo
	Salix discolor	Pussy Willow
	Salix bebbiana	Bebb Willow

References: Barnes and Wagner 1981, Vines 1984, Nierung 1985, MDNR 1971 and 1994

Table A-3
Insect Species Potentially Occurring In or Near the API/PC/KR Area

Family	*Species*	*Common Name*
Arthropods (Phylum Arthropoda) (aquatic and terrestrial)		
Insects	***Class Insecta***	
	Order Hymenoptera	Ants, Bees, Wasps
	Order Diptera - (Two species of aquatic Diptera)	Flies, Midges, Mosquitoes
	Order Odonata - Two species of Odonata	Dragonflies and Damselflies
	Order Ephemeroptera - Six species of Ephemeroptera	Mayflies
	Order Tricoptera - Five species of Trichoptera	Caddisflies
	Order Plecoptera	Stoneflies
	Order Orthoptera	Grasshoppers and Crickets
	Order Coleoptera - Two species of aquatic Coleoptera	Beetles
	Order Hemiptera	True Bugs
	Order Lepidoptera - One species of aquatic Lepidoptera	Butterflies and moths
	Class Arachnida	Spiders, Scorpions, Mites, Ticks
	Class Isopoda	Isopods
	Class Branchiopoda - One species of Daphnia	Cladocerans
	Class Amphipoda	Amphipods
	Class Chilopoda	Centipedes
	Class Diplopoda	Millipedes
Flatworms Phylum Platyhelminthes		
	Class Turbellaria - two species	Turbellarians
Segmented Worms and Leeches		
Phylum Annelida	*Class Oligochaeta*	Earthworms and related worms
	Class Hirudinea	Leeches
Molluscs		
Phylum Mollusca	*Class Gastropoda - Two species of Gastropoda*	Snails and Slugs
	Class Bivalvia	Freshwater Clams
Bryozoans		
Phylum Ectoprocta	*- two species of Bryozoa*	

References: MDNR 1987, Niering 1985, Milne and Milne 1980.

Table A-4
Fish Species Potentially Occurring In or Near the API/PC/KR Area

Family	Species	Common Name
Amiidae	*Amia calva*	Bowfin
Clupeidae	*Alosa pseudoharengus*	Alewife
	Dorsoma cepedianum	Gizzard shad
Umbridae	*Umbra limi*	Central mudminnow
	Esox americanus	Mud pickerel
	Esox lucius	Northern pike
Characidae	*Cyprinus carpio*	Common Carp
	Notemigonus crysoleucas	Golden shiner
	Semotilus atromaculatus	Creek chub
	Nocomis biguttatus	Hornyhead chub
	Rhinichthys atratulus	Blacknose dace
	Luxilus chrysocephalus	Striped shiner
	Luxilus cornutus	Common shiner
	Cyprinella spilopterus	Spotfin shiner
	Pimephales notatus	Bluntnose minnow
	Notropis atherinoides	Emerald shiner
	Notropis ludibundus	Sand shiner
	Notropis volucellus	Mimic shiner
	Notropis hudsonius	Spottail shiner
Catostomidae	*Carpiodes cyprinus*	Quillback
	Catostomus commersoni	White sucker
	Minytrema melanops	Spotted sucker
	Erimyzon oblongus	Creek chubsucker
	Hypentelium nigricans	Northern hog sucker
	Moxostoma breviceps	Shorthead redhorse
	Moxostoma duquesnei	Black redhorse
	Moxostoma erythrurum	Golden redhorse
	Moxostoma anisurum	Silver redhorse
	Moxostoma macrolepidotum	Northern redhorse
Ictaluridae	*Ameiurus natalis*	Yellow bullhead
	Ameiurus melas	Black bullhead
	Ameiurus nebulosus	Brown bullhead

Table A-4
Fish Species Potentially Occurring In or Near the API/PC/KR Area

Ictaluridae con't	*Ictalurus punctatus*	Channel catfish
	Pylodictis olivaris	Flathead catfish
	Noturus flavus	Stonecat
	Noturus gyrinus	Tadpole madtom
Aphredoderidae	*Aphredoderus sayanus*	Pirate perch
Gadidae	*Lota lota*	Burbot
Atherinidae	*Labidesthes sicculus*	Brook silverside
Centrarachidae	*Pomoxis nigromaculatus*	Black crappie
	Ambloplites rupestris	Rock bass
	Micropterus salmoides	Largemouth bass
	Micropterus dolomieu	Smallmouth bass
	Lepomis cyanellus	Green sunfish
	Lepomis macrochirus	Bluegill
	Lepomis gibbosus	Pumpkinseed
	Lepomis megalotis	Longear sunfish
Percidae	*Stizostedion vitreum*	Walleye
	Perca flavescens	Yellow perch
	Percina maculata	Blackside darter
	Percina caprodes	Logperch
	Etheostoma nigrum	Johnny darter
	Etheostoma exile	Iowa darter
Sciaenidae	*Aplodinotus grunniens*	Freshwater drum

Amphibians

Table A-4 identifies all amphibian species and subspecies that occur within the general site area. Occurrence onsite is expected to be limited by specific habitat requirements. Species recently observed onsite are identified with an asterisk (*).

Table A-5
Amphibians Potentially Occurring In or Near the API/PC/KR Area

Family	***Species***	***Common Name***
Proteidae	*Necturus masculosus*	Mudpuppy
Sirenidae	*Siren intermedia nettingi*	Western Lesser Siren
Ambystomatidae	*Ambystoma laterale*	Blue Spotted Salamander
	Ambystoma maculatum	Spotted Salamander
	Ambystoma opacum	Marbled Salamander
	Ambystoma tigrinum tigrinum	Tiger Salamander
Salamandridae	*Notophthalmus viridescens louisianensis*	Central Newt
Plethodontidae	*Plethodon cinereus*	Red-Backed Salamander
	Hemidactylium scutatum	Four-Toed Salamander
Bufonidae	**Bufo americanus americanus*	Eastern American Toad
	Bufo woodhousii fowleri	Fowler's Toad
Hylidae	*Acris crepitans blanchardi*	Blanchard's Cricket Frog
	Pseudacris triseriata triseriata	Western Chorus Frog
	Pseudacris triseriata maculata	Boreal Chorus Frog
	Pseudacris crucifer crucifer	Northern Spring Peeper
	Hyla versicolor	Eastern Gray Treefrog
	Hyla chrysoscelis	Cope's Gray Treefrog
Ranidae	*Rana clamitans melanota*	Green Frog
	**Rana catesbeiana*	Bull Frog
	**Rana pipiens*	Northern Leopard Frog
	Rana palustris	Pickerel Frog
	Rana sylvatica	Wood Frog

References: Conant 1975, Behler and King 1979, Harding 1992

Reptiles

Table A-5 identifies all reptile species and subspecies that occur within the general site area. Occurrence onsite is expected to be limited by specific habitat requirements. Species recently observed onsite are identified with an asterisk (*).

Table A-6
Reptiles Potentially Occurring In or Near the API/PC/KR Area

Family	***Species***	***Common Name***
Chelydridae	**Chelydra serpentina*	Common Snapping Turtle
Kinosternidae	*Sternotherus odoratus*	Musk Turtle (Stinkpot)
Emydidae	*Clemmys guttata*	Spotted Turtle
	Clemmys insculpta	Wood Turtle
	**Terrapene carolina carolina*	Eastern Box Turtle
	Emydoidea blandingii	Blanding's Turtle
	**Graptemys geographica*	Map Turtle
	**Chrysemys picta marginata*	Midland Painted Turtle
Trionychidae	*Trionyx spinifera spinifera*	Eastern Spiny Softshell
Scincidae	*Eumeces fasciatus*	Five Lined Skink
Colubridae	*Clonophis kirtlandii*	Kirtland's Water Snake
	Nerodia erythrogaster neglecta	Northern Copperbelly Snake
	Nerodia sipedon sipedon	Northern Water Snake
	Regina septemvittata	Queen Snake
	Storeria dekayi	Brown Snake
	Storeria occipitomaculata occipitomaculata	Northern Redbellied Snake
	**Thamnophis sirtalis sirtalis*	Eastern Garter Snake
	Thamnophis sauritus septentrionalis	Northern Ribbon Snake
	Diadophis punctatus edwardsi	Northern Ringneck Snake
	Heterodon platyrhinos	Eastern Hognose Snake
	Coluber constrictor foxi	Blue Racer
	Elaphe obsoleta obsoleta	Black Rat Snake
	Lampropeltis triangulum triangulum	Eastern Milk Snake
	Opheodrys vernalis vernalis	Eastern Smooth Green Snake
Viperidae Crotalinae	*Sistrurus catenatus catenatus*	Eastern Massasauga Rattlesnake

References: Conant 1975, Behler and King 1979, Harding 1990, Holman 1989

* Species recently observed

Table A-7
Avian Species Potentially Occurring In or Near the API/PC/KR Area

Family	*Species*	*Common Name*	*Status*	*Abundance*
Gaviidae	*Gavia immer*	Common Loon	Transient	Accidental
Ardeidae	*Ardea herodias*	Great blue heron	Summer	Irregular
Gruidae	*Grus canadensis*	Sandhill crane	Transient	Accidental
Anatidae	*Cygnus columbianus*	Whistling swan	Transient	Accidental
	Cygnus buccinator	Trumpeter swan	Transient	Accidental
	Chen caerulescens	Snow Goose	Transient	Accidental
	Anser c. caerulescens	Blue goose	Transient	Accidental
	Branta canadensis	Canada goose	Transient	Irregular
	Anas platyrhynchos	Mallard duck	Permanent	Common
	Anas rubripes	Black duck	Permanent	Irregular
	Anas strepera	Gadwall	NA	NA
	Anas crecca	Green winged teal	Summer	Irregular
	Anas acuta	Northern pintail	NA	NA
	Anas discors	Blue winged teal	Summer	Irregular
	Aix sponsa	Wood duck	Summer	Uncommon
	Aythya valisineria	Canvasback duck	NA	NA
	Aythya americana	Redhead duck	NA	NA
	Aythya affinis	Lesser scaup	Transient	Accidental
	Bucephala clangula	Common goldeneye	Winter	Common
	Bucephala albeola	Bufflehead	NA	NA
	Mergus merganser	American merganser	Winter	Accidental
Rallidae	*Porphyrula martinica*	American gallinule	NA	NA
	Fulica americana	American coot	Transient	Accidental
Charadriidae	*Charadrius vociferus*	Killdeer	Summer	Common
Scolopacidae	*Tringa solitaria*	Solitary sandpiper	Transient	Irregular
	Actitis macularia	Spotted sandpiper	Transient	Rare
	Gallinago gallinago	Wilson's snipe	Transient	Irregular
	Scolopax minor	American woodcock	Transient	Rare
	Calidris melantos	Pectoral sandpiper	Transient	Accidental
	Bartramia longicauda	Upland sandpiper	NA	NA

Table A-7
Avian Species Potentially Occurring In or Near the API/PC/KR Area

Family	Species	Common Name	Status	Abundance
Laridae	*Larus philadelphia*	Bonaparte's gull	Transient	Accidental
	Larus delawarensis	Ring-billed gull	Transient	Rare
	Larus argentatus	Herring gull	Transient	Rare
	Chlidonias niger	Black tern	Transient	Accidental
Cathartidae	*Cathartes aura*	Turkey vulture	Summer	Uncommon
Accipitridae	*Aquila chrysaetos*	Golden eagle	NA	NA
	Haliaeetus leucocephalus	Bald eagle	Permanent	Uncommon
	Accipiter striatus	Sharp-shinned hawk	Transient	Uncommon
	Accipiter cooperii	Cooper's hawk	Permanent	Rare
	Buteo lineatus	Red-shouldered hawk	Transient	Rare
	Buteo platypterus	Broad-winged hawk	Transient	Irregular
	Buteo jamaicensis	Red-tailed hawk	Permanent	Uncommon
	Buteo lagopus	Rough-legged hawk	Winter	Irregular
	Pandion haliaetus	Osprey	Transient	Irregular
Phasianidae	*Bonasa umbellus*	Ruffed grouse	Permanent	Uncommon
	Colinus virginianus	Bobwhite quail	Permanent	Uncommon
	Phasianus colchicus	Ring-necked pheasant	Permanent	Common
	Meleagris gallopavo	Wild turkey	Permanent	Common
Columbidae	*Columba livia*	Rock dove	Permanent	Common
	Zenaida macroura	Mourning dove	Permanent	Common
Cuculidae	*Coccyzus americanus*	Yellow-billed cuckoo	Summer	Uncommon
	Coccyzus erythropthalmus	Black-billed cuckoo	Summer	Uncommon
Tytonidae & Strigidae	*Tyto alba*	Barn owl	NA	NA
	Asio flammeus	Short-eared owl	Winter	Accidental
	Asio otus	Long-eared owl	Winter	Accidental
	Bubo virginianus	Great horned owl	Permanent	Uncommon
	Strix varia	Barred owl	Summer	Accidental
	Otus asio	Screech owl	Permanent	Uncommon
	Aegolius acadicus	Northern saw-whet	Transient	Accidental

Table A-7
Avian Species Potentially Occurring In or Near the API/PC/KR Area

Family	*Species*	*Common Name*	*Status*	*Abundance*
Caprimulgidae	*Caprimulgus vociferus*	Whip-poor-will	Transient	Accidental
	Chordeiles minor	Common nighthawk	Transient	Uncommon
Trochilidae	*Archilochus colubris*	Ruby throated-hummingbird	Summer	Rare
Alcedinidae	*Ceryle alcyon*	Belted kingfisher	Permanent	Uncommon
Picidae	*Melanerpes carolinus*	Red bellied-woodpecker	Permanent	Uncommon
	Melanerpes erythrocephalus	Red headed-woodpecker	Summer	Common
	Picoides pubescens	Downy woodpecker	Permanent	Common
	Picoides villosus	Hairy woodpecker	Permanent	Uncommon
	Dryocopus pileatus	Pileated woodpecker	Transient	Accidental
Tyrannidae	*Tyrannus tyrannus*	Eastern Kingbird	Summer	Common
	Myiarchus crinitus	Great crested-flycatcher	Summer	Common
	Sayornis phoebe	Eastern phoebe	Summer	Uncommon
	Empidonax virescens	Acadian flycatcher	Summer	Irregular
	Empidonax traillii	Willow flycatcher	Summer	Common
	Empidonax flaviventris	Yellow bellied-flycatcher	Transient	Irregular
Alaudidae	*Eremophila alpestris*	Horned lark	Permanent	Common
Hirundinidae	*Tachycineta bicolor*	Tree swallow	Summer	Common
	Progne subis	Purple martin	Summer	Uncommon
	Riparia riparia	Bank Swallow	Transient	Irregular
	Stelgidopteryx serripennis	Rough-winged swallow	Transient	Irregular
	Hirundo pyrrhonota	Cliff Swallow	Transient	Accidental
	Hirundo rustica	Barn Swallow	Summer	Common
Corvidae	*Cyanocitta cristata*	Blue jay	Permanent	Common
	Corvus brachyrhynchos	Common Crow	Permanent	Common
Paridae	*Parus bicolor*	Tufted titmouse	Permanent	Common
	Parus atricapillus	Black capped-chickadee	Permanent	Common
Certhiidea	*Certhia americana*	Brown creeper	Winter	Uncommon
Sittidae	*Sitta carolinensis*	White breasted-nuthatch	Permanent	Common
	Sitta canadensis	Red breasted-nuthatch	Transient	Rare

Table A-7
Avian Species Potentially Occurring In or Near the API/PC/KR Area

Family	*Species*	*Common Name*	*Status*	*Abundance*
Troglodytidae	*Troglodytes aedon*	House wren	Summer	Common
	Troglodytes troglodytes	Winter wren	Transient	Uncommon
	Cistothorus palustris	Marsh wren	Transient	Accidental
Muscicapidae	*Regulus satrapa*	Golden crowned-kinglet	Transient	Common
	Regulus calendula	Ruby crowned-kinglet	Transient	Common
	Polioptilla caerulea	Blue-gray gnatcatcher	Summer	Irregular
	Sialia sialis	Eastern bluebird	Summer	Common
	Hylocichla mustelina	Wood thrush	Summer	Uncommon
	Catharus fuscescens	Veery	Transient	Uncommon
	Catharus ustulatus	Swainson's thrush	Transient	Common
	Catharus minimus	Gray-cheeked thrush	Transient	Common
	Catharus guttatus	Hermit thrush	Transient	Common
	Turdus migratorius	American robin	Summer	Common
Laniidae	*Lanius ludovicianus*	Loggerhead shrike	Transient	Accidental
	Lanius excubitor	Northern shrike	Winter	Accidental
Mimidae	*Dumetella carolinensis*	Gray catbird	Summer	Common
	Mimus polyglottos	Mockingbird	Summer	Accidental
	Toxostoma rufum	Brown thrasher	Summer	Common
Cinclidae	*Bombycilla cedrorum*	Cedar waxwing	Permanent	Common
Sturnidae	*Sturnus vulgaris*	European Starling	Permanent	Common
Vireonidae	*Vireo flavifrons*	Yellow-throated vireo	Summer	Rare
	Vireo solitarius	Solitary vireo	Transient	Rare
	Vireo olivaceus	Red-eyed vireo	Summer	Common
	Vireo philadelphicus	Philadelphia vireo	Transient	Rare
Emberizidae	*Vermivora pinus*	Blue-winged warbler	Summer	Common
	Vermivora chrysoptera	Golden winged-warbler	Transient	Uncommon
	Vermivora peregrina	Tennessee warbler	Transient	Common
	Vermivora celata	Orange crowned-warbler	Transient	Rare
	Vermivora ruficapilla	Nashville warbler	Transient	Common
	Dendroica caerulescens	Black-throated blue-warbler	Transient	Uncommon
	Dendroica cerulea	Cerulean warbler	Transient	Rare

Table A-7
Avian Species Potentially Occurring In or Near the API/PC/KR Area

Family	Species	Common Name	Status	Abundance
	Dendroica fusca	Blackburnian warbler	Transient	Uncommon
Emberizidae con't	*Dendroica pennsylvanica*	Chesnut-sided-warbler	Transient	Common
	Dendroica coronata	Yellow rumped-warbler	Transient	Common
	Dendroica virens	Black-throated green-warbler	Transient	Common
	Dendroica pinus	Pine warbler	Transient	Irregular
	Dendroica palmarum	Palm warbler	Transient	Uncommon
	Dendroica petechia	Yellow warbler	Summer	Common
	Oporornis philadelphia	Mourning Warbler	Transient	Irregular
	Oporornis agilis	Connecticut Warbler	Transient	Accidental
	Wilsonia canadensis	Canada warbler	Transient	Uncommon
	Wilsonia pusilla	Wilson's Warbler	Transient	Uncommon
	Wilsonia citrina	Hooded warbler	Transient	Accidental
	Seiurus aurocapillus	Ovenbird	Summer	Common
	Seiurus motacilla	Louisiana water-thrush	Summer	Irregular
	Seiurus noveboracensis	Northern water-thrush	Transient	Rare
	Geothlypis trichas	Common yellow-throat	Summer	Common
	Setophaga ruticilla	American Redstart	Transient	Common
	Cardinalis cardinalis	Northern Cardinal	Permanent	Common
	Passerina cyanea	Indigo bunting	Summer	Common
	Pipilo erythropthalmus	Rufous-sided towhee	Summer	Common
	Ammodramus savannarum	Grasshopper sparrow	Summer	Uncommon
	Ammodramus henslowii	Henslow's sparrow	Summer	Irregular
	Pooecetes gramineus	Vesper sparrow	Summer	Uncommon
	Melospiza melodia	Song sparrow	Permanent	Common
	Spizella arborea	Tree sparrow	Winter	Common
	Spizella pusilla	Field sparrow	Summer	Common
	Spizella pallida	Clay-colored sparrow	Transient	Accidental
	Junco hyemalis	Dark-eyed junco	Winter	Common
	Zonotrichia albicollis	White throated-sparrow	Transient	Common
	Zonotrichia leucophrys	White crowned-sparrow	Transient	Common
	Passerella iliaca	Fox sparrow	Transient	Uncommon

Table A-7
Avian Species Potentially Occurring In or Near the API/PC/KR Area

Family	*Species*	*Common Name*	*Status*	*Abundance*
	Melospiza lincolnii	Lincoln's sparrow	Transient	Rare
Emberizidae con't	*Melospiza georgiana*	Swamp sparrow	Transient	Uncommon
	Dolichonyx oryzivorus	Bobolink	Summer	Uncommon
	Sturnella magna	Eastern Meadowlark	Summer	Common
	Sturnella neglecta	Western Meadowlark	Summer	Accidental
	Agelaius phoeniceus	Red-winged blackbird	Summer	Common
	Molothrus ater	Brown headed-cowbird	Summer	Common
	Quiscalus quiscalus	Common grackle	Summer	Common
	Icterus spurius	Orchard oriole	Summer	Accidental
	Icterus galbula	Northern oriole	Summer	Common
	Piranga olivacea	Scarlet tanager	Summer	Uncommon
Passeridae	*Passer domesticus*	House sparrow	Permanent	Common
Fringillidae	*Carduelis tristis*	American goldfinch	Permanent	Common
	Carpodacus purpureus	Purple finch	Winter	Common
	Coccothraustes vespertinus	Evening grosbeak	Winter	Irregular

Definitions:

Permanent resident	Species which remain year round and breed in the area during Spring and/or Summer.
Summer resident	Species which nest in the area, but migrate to the south for the winter.
Winter resident	Species which arrive in the Fall and leave for more northern breeding grounds in the Spring.
Transient resident	Species which pass through in the Spring and/or Fall and normally do not remain in Summer or Winter.
Common	Regularly recorded in large numbers.
Uncommon	Regularly recorded in small numbers.
Rare	Seldom recorded more than two or three times per year/season.
Irregular	Not recorded every year, but may be somewhat common in certain areas.
Accidental	Recorded on less than five occasions.
NA	Data not available.

References: Adams 1974, McPeek and Adams 1994, National Geographic Society (2nd ed.)

Mammals

Table A-7 identifies mammals whose range encompasses the general site area. Species examples are the most common or wide-ranging species within the group. Rare mammals, those known to occur only within certain limited areas, or those that do not occur in areas impacted by human use are not included.

Table A-8
Mammals Potentially Occurring In or Near the API/PC/KR Area

Family	Species	Common Name
Didelphidae	*Didelphis virginiana*	Opossum
Soricidae	*Sorex cinereus*	Masked shrew
	Blarina brevicauda	Short-tailed shrew
	Cryptotis parva	Least shrew
Talpidae	*Scalopus aquaticus*	Eastern mole
	Condylura cristata	Star-nosed mole
Vespertilionidae	*Myotis lucifugus*	Little brown bat
	Lasionycteris noctivagans	Silver-haired bat
	Eptesicus fuscus	Big brown bat
	Lasiurus borealis	Red bat
	Lasiurus cinereus	Hoary bat
	Nycticeius humeralis	Evening bat
Leporidae	*Sylvilagus floridanus*	Eastern cottontail
Sciuridae	*Tamias striatus*	Eastern chipmunk
	Marmota monax	Woodchuck
	Spermophilus franklinii	Franklin's ground squirrel
	Spermophilus tridecemlineatus	Thirteen-lined ground squirrel
	Sciurus carolinensis	Gray squirrel
	Sciurus niger	Fox squirrel
	Tamiasciurus hudsonicus	Red squirrel
	Glaucomys sabrinus	Northern flying squirrel
	Glaucomys volans	Southern flying squirrel
Castoridae	*Castor canadensis*	Beaver
Cricetidae	*Peromyscus leucopus*	White-footed mouse
	Peromyscus maniculatus	Deer mouse
	Microtus pennsylvanicus	Meadow vole
	Microtus pinetorum	Woodland vole
	Ondatra zibethicus	Muskrat
	Synaptomys cooperi	Southern bog lemming

Table A-8
Mammals Potentially Occurring In or Near the API/PC/KR Area

Family	***Species***	***Common Name***
Muridae	*Mus musculus*	House mouse
Zapodidae	*Zapas hudsonius*	Meadow jumping mouse
Canidae	*Canis latrans*	Coyote
	Vulpes vulpes	Red fox
	Urocyon cinereoargenteus	Gray fox
Procyonidae	*Procyon lotor*	Raccoon
Mustelidae	*Mustela erminea*	Ermine
	Mustela frenata	Long-tailed weasel
	Mustela nivalis	Least weasel
	Mustela vison	Mink
	Taxidea taxus	Badger
	Mephitis mephitis	Stiped Skunk
	Lutra canadensis	River otter
Cervidae	*Odocoileus virginianus*	White-tailed deer

References: Baker 1983, Davis 1978

Appendix B

EXPOSURE-RELATED (LIFE HISTORY) DATA FOR REPRESENTATIVE RECEPTORS

Red Fox (Vulpes vulpes)

Red fox are native to most of North America, but are most abundant in Canada and the northern United States. Red fox are most often found in rural areas, however they may also inhabit small areas within urban communities where suitable habitat is available. In Michigan, red fox are found in every county and on most of the major islands of the Great Lakes.

Habitat. Red fox prefer habitats that provide both adequate cover and prey. The most suitable habitats for red fox are fallow fields, cultivated fields, meadows, bushy fence lines, woody streams, and low shrub cover adjacent to woodlands or water bodies (Baker 1983). Red fox construct burrows which are used as refuges and for rearing young. The burrows are usually located in a well-drained area, however, red fox may sometimes construct dens on river islands (Arnold 1956). These burrows may extend 10 to 30 feet below the ground surface (Baker 1983).

Density and Movement. Red fox are highly mobile, and forage extensively when food is limited. The home range is dependent on topography, vegetation, and prey availability (Baker 1983). Typically, a home range area will be comprised of an adult pair, their offspring, and occasionally a stray adult. The home range of red fox varies seasonally. During autumn, juvenile foxes are dispersing from the burrows in search for their own home range. Males will disperse an average of 18.4 miles during late September to early October. However, females will only disperse an average of 6.2 miles and do not leave the burrow until a month after the males (Phillips, et al. 1972). In the winter months the daily average home range is 900 acres, and nightly travels average five miles (Arnold and Schofield 1956). In the spring, there is commonly one fox family, averaging 7.4 individuals, sharing a home range of 2,471 acres (Shick 1952). In Michigan, the typical home range for a pair of red fox is 1,200 acres (Murie 1936).

Behavior. Red fox are nocturnal, and are active eight to 10 hours per 24 hour day. Eighty percent of this time is spent traveling. Red fox are also capable of swimming, which allows utilization of streams and rivers for food sources. In addition, red fox are burrowing animals and therefore spend much of their time digging.

Reproductive Activities. Red fox are capable of producing one litter of pups per year. The breeding season begins in December and continues through March. The gestation period is 51-54 days. The average litter is five pups (average range is 4 to 6 pups), depending on location. In the Upper Peninsula of Michigan, the average litter is four pups, while six pups are average in the Lower Peninsula (Schofield 1958). The pups are weaned at 60 days, and after 120 days the pups are able to hunt. The average life expectancy of a red fox is three years (Baker 1983). Hunting and trapping account for 80 percent of fox mortalities (Baker 1983). There is also evidence that red fox populations fluctuate in 10 year cycles (Baker 1983).

Food Habits. Red fox are omnivores, but about 90 percent of the diet is of animal origin. Red fox consume on average 10 percent plants, 20 percent invertebrates, 15 percent reptiles and amphibians (herps), 15 percent birds, and 40 percent mammals (US EPA 1994). The diet includes several species identified in the Kalamazoo River Food Web, including deer mice, muskrat, mink, snapping turtles, and great horned owls.

Economic Importance. Red fox are hunted and trapped. Their furs are valued at $5 to $150 each, depending on the annual supply and demand (Baker 1983).

Deer Mouse (*Peromyscus maniculatus bairdii*)

Deer mice are small ground-dwelling rodents that live in a wide variety of habitats throughout North America. The genus *Peromyscus* is wide-spread throughout North America. The subspecies *bairdii* is most common in the southwestern portions of Michigan. Deer mice are distinguished by large black beady eyes, pointed nose, and long whiskers. On average adult deer mice are 4.8 to 6.2 inches in length and weigh from 0.4 to 0.8 ounces (Baker 1983).

Habitat. Deer mice are found in a wide variety of habitats and are capable of adapting to many environments, including sandy beaches or lake shores, the edges of marshes, open woodlands, agricultural areas, and grassy fields and prairies (Baker 1983).

Density and Movement. The density of deer mice in any given area is a function of food supplies, habitat quality, and spatial needs of individual animals (Baker 1983). Deer mice populations also fluctuate seasonally. All wild deer mice populations experience an annual low in the early spring due to winter die-off and predation. This annual low is followed by a population explosion in the late spring (Howard 1949).

Deer mice are typically sedentary, and have home ranges from 0.5 to 2.5 acres (Baker 1983). Male deer mice have larger home ranges than females. Male home ranges encompass the home ranges of many females (Cranford 1984). The female's home range encompasses their foraging and nesting areas (Cranford 1984). Woodland deer mice, on average, have larger home ranges than prairie deer mice (Blair 1942).

Behavior. The behaviors of deer mice are categorized into three classes: (1) Motor Patterns, (2) Sensory Capacities, and (3) Learning Ability (King 1968). Motor patterns refer to the ability to swim, climb, gather food, and move around within its home range, while sensory capacities refer to the ability to detect light, odor, taste, temperature, gravity, and sound. Learning ability, which is generally unknown in wild populations, is measured by using mazes and rewards. In the winter months deer mice tend to congregate in one nest to conserve heat (Howard 1951). Within this group are three basic social units: (1) a mature male, (2) a mature female, and (3) juveniles.

Reproductive Activities. Deer mice reach sexual maturity 35 days after birth (EPA 1993). The breeding season extends from March through November. As the temperature increases in the spring, the reproduction rate of deer mice also increases. Each mouse is capable of producing two or three litters per breeding season (Johnson, et al. 1970). An average litter size includes four to six mice. Deer mice are also able to have consecutive litters without an estrus cycle (Baker 1983). Over a one year period the mortality rate of deer mice is 95 percent (Hansen, et al. 1974).

Food Habits. The average diet of deer mice is comprised of 60 percent terrestrial plants and 40 percent terrestrial invertebrates (CDM 1994). Food items may include insects, other invertebrates, seeds, fruits, flowers, and plants (Baker 1983). During periods of food shortages, deer mice will consume fecal pellets to sustain themselves (Baker 1983).

Predators. Deer mice serve as prey for many different animals including owls, hawks, snakes, coyotes, foxes, mink, and domestic cats.

Economic Importance. Deer mice serves a useful purpose in the environment as a principal food item for a wide variety of carnivores, including valuable fur-bearing animals such as mink (Baker 1983).

American Robin (Turdus migratorius)

The American robin is a medium-sized migratory bird found throughout the United States, Canada, Mexico, and Central America, and is distinguished by its black or dark grey/brown plumage with a dark orange breast.

Habitat. The American robin is found in a large variety of habitats. The preferred habitats are moist forests, swamps, open woodlands, orchards, parks, and suburban lawns. These types of habitat provide the robin with adequate cover, foraging areas, and water supplies (EPA 1993). The American robin utilizes trees or hedges for nesting sites.

Density and Movement. The density of the American robin is dependent on the type of cover available and the abundance of food supplies. Areas with very dense cover and adequate foraging areas yield very high densities of nesting robins, while areas with sparse cover do not support high densities of birds (EPA 1993). American robins are migratory, and spend the winter months in the southern United States, Mexico, and Central America. In the early spring they migrate to the northern United States and Canada. Male robins will return to the summer breeding ground just before the female robins arrive. This allows the males to establish breeding territories. It is very common for the same birds to return to the same breeding grounds year after year (EPA 1993). During the summer months, at the peak of the breeding season, the home range of the American robin is approximately 0.33 acres (CDM 1994). In the winter months when the robin is migrating southward the home range can be very large.

Reproductive Activity. The breeding season of the American robin begins in April and extends through July. As the males return from their wintering grounds they establish dominant breeding territories. Then as the females return, the males defend their territory from other males. Once a pair of robins mate, they remain united for the entire breeding season (Young 1951). The female prepares the nest from dried vegetation and mud. Only the female incubates the eggs, and incubation lasts for 10 to 14 days (EPA 1993). A female's first clutch usually produces three or four eggs. Later clutches produce fewer eggs. Once the eggs hatch, both the male and female participate in feeding the nestlings (Young 1955). After the nestlings are able to fly, the family forms a foraging flock and feeds together in areas of high food availability (EPA 1993). The longevity of the American robin is from 1.3 to 1.4 years (Farner 1949). Half of the adult birds survive from year to year.

Food Habits. The American Robin consumes a combination of fruits and invertebrates. During the breeding season, the diet may be composed of 90 percent invertebrates and 10 percent vegetation. However, the rest of the year the robins diet is usually comprised of 80 to 99 percent fruit and one to 20 percent invertebrates (Martin, et al. 1951). The robin's food choices for fruits include plums, dogwood, summac, hackberries, blackberries, cherries, greenbriers, and raspberries. The robin's food choices for invertebrates include beetles, caterpillars, moths, grasshoppers, spiders, millipedes, and earthworms. The American robin's daily intake of food must exceed their body weight to meet their metabolic needs (Karasov and Levey 1990). Robins have a digestive efficiency of 55 percent for fruits and 70 percent for invertebrates (Karasov and Levey 1990).

Predators. Predation is the leading cause of mortality for the American robin (EPA 1993).

Economic Importance. The American robin is not economically important, but is the state bird of Michigan. In addition, all songbirds are protected by Federal law.

Great Horned Owl (Bubo virginianus)

Great horned owls, found throughout the United States and Canada, are the largest and most powerful owl. They are recognized by brown spotted plumage, white throat feathers, and the distinguishing characteristic of "ears" that point upward, making these owls look as if they have horns growing from their heads.

Habitat. Great horned owls may be found in a wide variety of habitats ranging from wooded wilderness to urban parks. The most suitable habitats for great horned owls are woods, marshes, dunes, open deserts, and mountainous regions which provide abundant hunting areas (Terres 1980).

Density and Movement. The home range of great horned owls is approximately 180 acres (CDM 1994).

Behavior. Great horned owls do not construct a nest but instead utilize old hawk, eagle, or crow nests. They prefer to use nests that are situated in the hollow of a tree or on the edge of a cliff (Terres 1980).

Reproductive Activity. Winter is the breeding season for great horned owls, and eggs are usually laid in January or February. Each female is capable of laying from one to 6 eggs. The incubation period ranges from 26 to 30 days, and only the female incubates eggs (Granlund, et al. 1994). After hatching, it takes 63 to 70 days before nestlings start to fly (Terres 1980). Great horned owls may live up to 29 years (Terres 1980).

Food Habits. Great horned owls are primarily nocturnal, and use old abandoned nests to roost and consume prey. Prey includes rabbits, squirrels, chipmunks, mink, weasels, skunks, woodchucks, opossum, snakes, cats, bats, and birds (Terres 1980). Of these, rabbits are the most preferred. Average dietary composition consists of approximately 20 percent invertebrates, 20 percent herps, 20 percent birds, and 40 percent mammals (CDM 1994).

Muskrat (Ondatra zibethicus)

Muskrats are semi-aquatic mammals found throughout North America. They are one of the largest rodents found in Michigan, and are recognized by robust size, long-flattened tail, and dense fur which provides insulation and buoyancy.

Habitat. Muskrats are found in a large variety of aquatic environments, especially marshes with constant water levels and no flowing water (Johnson 1925). Less favorable habitats for muskrats are ponds, lakes, streams, canals, reservoirs, and swamps (Johnson 1925). The high productivity of marshes make them the most suitable environment for muskrats providing that the water level does not drop below four to six feet. Low water levels during the winter months can result in freeze out and high mortality among local muskrat communities (Baker 1983). Marshes are also most suitable for muskrats due to the diversity of the vegetation which provides food resources and materials for den construction.

Density and Movement. The density of muskrat populations is affected by severe winters, flooding, drought, disease, and over-trapping (Errington 1939). On average, there are one to three muskrats per acre in habitats of low suitability. Under optimum conditions there may be as many as 35 muskrats per acre (Banfield 1974). Muskrats experience annual and semi-annual fluctuations in their populations due to periods of high mortality and high reproduction (Baker 1983). Muskrats typically have a very small home range averaging about 0.05 acres (CDM 1994). During summer muskrats rarely stray more than about 600 feet from their dens, and during winter muskrats forage within about 36 feet of their dens (Baker 1983). Muskrats are capable of moving up to 20 miles during their lifetime (Errington 1939). The primary reasons why muskrats may travel such distances are: (1) overcrowding; (2) dispersal of young; (3) reproductive activity; (4) severe cold (winter freeze-out); (5) drought; and/or (6) food shortages (Baker 1983).

Behavior. Muskrats typically live in groups which consist of related individuals (Baker 1983). Muskrats are also territorial and use their scent glands to mark and maintain their territories. They usually have two different houses, one of which is a feeding house while the other is a dwelling and rearing den. These dens are typically constructed of vegetation and have multiple entrances and tunnels. Muskrats also dig burrows in the banks of rivers, streams, or lakes (Baker 1983). Muskrats may be active 24 hours a day. However, they usually forage in the late evening hours.

Reproductive Activities. The breeding season is from March to August. Females are capable of producing up to three litters per year, and each litter may have from one to 11 newborns. The average litter size is six. The normal gestation period is 25 to 35 days. Ten days after birth the young are capable of moving about the nest. At 14 to 16 days the newborns are able to swim. The young begin to consume green vegetation at 30 days. After about 200 days the young reach full independence (Baker 1983). The life expectancy for muskrats is three to four years. The mortality rate during the first year of life is 87 percent and increases to 98 percent during the second year (Baker 1983).

Food Habits. Muskrats are primarily herbivorous. They consume one third of their body weight in vegetation each day. During the summer months muskrats primarily consume emergent vegetation. However, in the winter months when emergent vegetation is scarce, muskrats will consume primarily submergent vegetation. The foods of choice for the muskrat include cattails, bulrush, arrowhead, water lily, corn, reed, and duckweed. When vegetation is limited, muskrats will consume crayfish, frogs, turtles, mollusks, and fish (Baker 1983).

Predators. Muskrats serve as prey to many different predators, including snapping turtles, bass, northern pike, pickerel, herons, bald eagles, owls, hawks, red fox, and mink (Errington 1939). Mink are the primary predators of muskrat (Errington 1943). Muskrats are also trapped for furs and meat.

Economic Importance. Muskrats are valued for their furs. They are the most important fur bearing animal in Michigan (Ruhl and Baumgartner 1942). In 1981, muskrat pelts were selling for $7.30 per pelt (Baker 1983). Muskrats are also valued for their meat, and muskrat meat can be found in markets for up to $0.70 per pound (Dufresne 1982).

Mink (Mustela vison)

Mink are long slender mammals with short legs, thick soft under fur, and long glossy oily guard hairs. Most mink are black and have a characteristic white blotch under their chin. Mink are one of the most abundant and widespread carnivores in North America, found across North America except in extremely arid regions of the southwest United States and Mexico and extreme northern regions of Canada (Baker 1983).

Habitat. Mink are semi-aquatic mammals, and may be found along streams, rivers, lakes, ponds, and marshes. They prefer habitat with irregular shorelines (Allen 1986). When away from water mink prefer mixed shrubs, weeds, and grasses. The only type of habitat that mink will not use on a regular basis is heavily wooded uplands (Baker 1983).

Density and Movement. The density of mink populations depends on food and habitat availability. Mink populations are highest in large marshes that contain cattails and numerous muskrat dens (Errington 1943). Mink populations are also a function of hunting and trapping seasons. Prior to the trapping season, mink density ranges from eight to 22 animals per square mile. After trapping season mink density ranges from three to four animals per square mile (Baker 1983). The movements of mink are influenced in part by intraspecific living space interaction (Baker 1983). The home range encompasses foraging areas, surrounding water ways, and dens (EPA 1993). A mink's home range depends on food availability, sex, and season (EPA 1993). The average home range for mink is about 20 acres (CDM 1994). However, along rivers or streams, male mink may travel up to 1.6 miles from their dens, while females travel up to 1.1 miles from their home site (Gerell 1970).

Behavior. Mink are generally nocturnal. They are also solitary except during the breeding season. Mink of the same sex usually avoid interactions with one another. Females are solely responsible for raising the young (Baker 1983). Mink usually establish their dens near water, and have a tendency to invade old beaver or muskrat dens (Baker 1983). Mink excavate ground burrows under root masses, beneath fallen logs, under brush piles, or in stream banks. Most tunnels are frequently inundated with water. Mink are also excellent swimmers, capable of diving to depths of 18 feet and swimming under water for distances up to 100 feet (Baker 1983).

Reproductive Activity. The breeding season begins in February and ends in April. Mink are only capable of producing one litter per year. The average litter size is four (EPA 1993). The mink's reproductive cycle is unique. After the egg is fertilized, the embryo goes dormant (Hannson 1947). The length of this dormancy depends on the amount of daylight during a 24 hour period (Holcomb 1963). Therefore, the total gestation period varies from 39 to 76 days. Only 30 to 32 days are needed for full development of the fetus (Enders 1952). The young are usually born in late April or May, and they are able to catch their own prey 42 to 56 days after birth. In August the young disperse because they no longer need maternal care (Baker 1983). The life expectancy of mink is three to four years (Baker 1983).

Food Habits. Mink are primarily carnivorous. However, they may consume some plant material from time to time (Baker 1983). The typical diet of the mink consists of approximately 30 percent fish, 20 percent herps, 20 percent birds, and 30 percent mammals (CDM 1994). Mink are opportunistic in food selection (Iverson 1972). Primary terrestrial food items include shrews, moles, squirrels, mice, rats, bats, rabbits, voles, and muskrats. In the winter, the primary food choice of the mink is either muskrat or rabbit (Baker 1983).

Predators. Humans are the main predator of mink. Hunters and trappers account for the majority of mink mortality. Other natural predators include great horned owls, red fox, and domestic animals (Baker 1983).

Economic Importance. Mink are economically important because of the value of their furs. Mink are commercially raised for their pelts. This has helped alleviate hunting and trapping pressures on wild mink (Baker 1983). However, mink pelts are still highly valued. In 1969, mink pelts sold for $12 each. By 1980 they were selling for $30 each (Baker 1983). With such trends, it is expected that mink furs will continue to be valued. The fur market is subject to highs and lows which are influenced by fashion trends, excise taxes, imports, and synthetic furs (Baker 1983).

Appendix C

TABLE C-1 Allied Paper, Inc/Portage Creek/Kalamazoo River Superfund Site - PCB Food Web Model

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Receptor	Total PCB Conc[1] (ABSAs 3-10) (ppm)	Method	Primary Exposure Media	Mean BCF/BAF	Home Range (hectares)	Site Foraging Frequency (SFF)[2]	Dietary Fraction (DF)	Total Dietary PCB Conc (B_{prey}*H) (mg/kg FW diet)	IR (g/d)	BW (g)	APDD (mg/kg/d) $\frac{I*J*G}{K}$	LOAEC (exposure duration) Species -Effect - Reference	Criteria, Threshold, or NOAEC
SW (range of U95) (mean of U95)	0.000016 - 0.000108 0.000043	Measured	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.000014 mg PCB/L - EPA 1980 or site-specific values
SED (range of U95) (mean of U95)	0.30-13.6 7.3	Measured	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	19.5 mg PCB/ kg carbon - EPA 1988b or site-specific values
FP SED (range of U95) (mean of U95)	0.20-21.1 14.0	Measured	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	see SED see SS
SS (range of U95) (mean of U95)	0.23-30.2 16.9	Measured	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Species specific LOAEC/(SUM (BAF*DF)SFF) - Boucher 1990
Algae (range of U95) (mean of U95)	0.016-0.108 0.043	Estimated (U95 PCB Conc SW *BCF)	SW	1000 (Diatom, Keil et al., 1971 in EPA 1980)	NA	NA	NA	NA	NA	NA	NA	0.0001 mg/L Algae (diatoms) - Delayed and Reduced Growth - Fisher and Wurster 1973 in EPA 1980	0.000014 mg PCB/L - EPA 1980 or site-specific values

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Receptor	Total PCB Conc[1] (ABSAs 3-10) (ppm)	Method	Primary Exposure Media	Mean BCF/BAF	Home Range (hectares)	Site Foraging Frequency (SFF)[2]	Dietary Fraction (DF)	Total Dietary PCB Conc (B_{prey} *H) (mg/kg FW diet)	IR (g/d)	BW (g)	APDD (mg/kg/d) $\frac{I*J*G}{K}$	LOAEC (exposure duration) Species -Effect - Reference	Criteria, Threshold, or NOAEC
Aquatic Macrophyte (range of U95) (mean of U95)	0.016 - 0.108 0.043	Estimated (U95 PCB Conc SW*BCF)	SW SED	1000 (Based on algae BCF, Keil et al. 1971 in EPA 1980)	NA	NA	NA	NA	NA	NA	NA	No Available Data	0.000014 mg PCB/L - EPA 1980 or site-specific values
Terrestrial Macrophyte (range of U95) (mean of U95)	0.3 -39.3 22	Estimated (U95 PCB Conc SS *BAF)	FP SED SS	1.3 (Trapp et al. 1990)	NA	NA	NA	NA	NA	NA	NA	No Available Data	None
Aquatic Invertebrate (Water Column) (range of U95) (mean of U95)	0.058-0.39 0.16	Estimated (U95 PCB Conc SW *BCF)	SW SED	3,650 (Mayer et al. 1977 in EPA 1980)	NA	NA	NA	NA	NA	NA	NA	0.0008 mg/L Midge Larva -	0.000014 mg PCB/L (SW) - EPA 198[illegible] or site-specific values
Aquatic Invertebrate (Benthic) (range of U95) (mean of U95)	0.26-1.7 0.69	Estimated (U95 PCB Conc SW *BCF)	SW SED	16,000 (Nebeker and Puglisi, 1974, in EPA 1980)	NA	NA	NA	NA	NA	NA	NA	0.0008 mg/L Nebeker and Puglisi 1974 in EPA 1980	19.5 mg PCB/ kg carbon (SED - EPA 1988b or site-specific values
Earthworm (range of max) (mean of max)	0.025-3.2 1.5	Measured (Max PCB Conc, WB)	SS FP SED	0.09 (calculated)	NA	NA	NA	NA	NA	NA	NA	No Available Data	None
Sucker (range of U95) (mean of U95)	0.49-2.8 1.7	Measured (U95 PCB Conc, WB)	SW SED	83,000 (calculated SW)	NA	NA	NA	NA	NA	NA	NA	0.0002 mg/L Fathead Minnow - Defoe et al. 1978 in EPA 1980	0.000014 mg PCB/L - EPA 1980 or site-specific values

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Receptor	Total PCB Conc[1] (ABSAs 3-10) (ppm)	Method	Primary Exposure Media	Mean BCF/BAF	Home Range (hectares)	Site Foraging Frequency (SFF)[2]	Dietary Fraction (DF)	Total Dietary PCB Conc (B_{prey} *H) (mg/kg FW diet)	IR (g/d)	BW (g)	APDD (mg/kg/d) $\frac{I*J*G}{K}$	LOAEC (exposure duration) Species -Effect - Reference	Criteria, Threshold, or NOAEC
Carp (range of U95) (mean of U95)	9.0-19.1 12.1	Measured (U95 PCB Conc, WB)	SW SED	583,000 (calculated SW)	NA	NA	NA	NA	NA	NA	NA	0.0002 mg/L Fathead Minnow - Defoe et al. 1978 in EPA 1980	0.000014 mg PCB/L - EPA 1980 or site-specific values
SM Bass (range of U95) (mean of U95)	1.8-8.7 5.4	Measured (U95 PCB Conc, WB)	SW Prey	249,000 (calculated SW)	NA	NA	NA	NA	NA	NA	NA	0.0004 mg/L Largemouth Bass - Acute LC50/Mean ACR for FW Fish - Birge et al. 1979 in EPA 1980	0.000014 mg PCB/L - EPA 1980 or site-specific values
Muskrat (range of max) (mean of max)	2.0-8.4 4.5	Measured (Max PCB Conc, WB)	SED FP SED Vegetation	Not Applicable because of unknown contribution from multiple exposure pathways	0.13 EPA 1993	1.0	Aquatic Plants 1.0 EPA 1993	0.043 TOTAL = 0.043	420 EPA 1993	1,400 EPA 1993	0.013	500 mg/kg FW diet (240 days) - (150 mg/kg-d) Rat - 15% Mortality - Kimbroughj et al. 1972 in EPA 1980	<0.5 mg/kg-d (rat NOAEC) - Grant 1983 in Eisler 1986

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Receptor	Total PCB Conc[1] (ABSAs 3-10) (ppm)	Method	Primary Exposure Media	Mean BCF/BAF	Home Range (hectares)	Site Foraging Frequency (SFF)[2]	Dietary Fraction (DF)	Total Dietary PCB Conc (B_{prey}*H) (mg/kg FW diet)	IR (g/d)	BW (g)	APDD (mg/kg/d) $\frac{I*J*G}{K}$	LOAEC (exposure duration) Species -Effect - Reference	Criteria, Threshold, or NOAEC
Mink (range of max) (mean of max)	 7.6-15.5 11.7	Measured (Max PCB Conc, WB)	Prey	Not Applicable because of unknown contribution from multiple exposure pathways	14.1 EPA 1993	1.0	Fish 0.38 Herps 0.13 Birds 0.09 Mammals 0.28 Aq. inverts 0.05 Aq./terr. plants 0.07 EPA 1993 Mammals = mean of max PCB conc for muskrat and mouse	2.4 0.44 0.08 0.69 0.03 0.77 Total = 4.4	190 EPA 1993	1,354 EPA 1993	0.62	0.69 mg/kg FW diet (variable) - (0.1 mg/kg-d) Mink - Reproductive Effects - (see text)	0.069 mg/kg FW diet (variable) - (0.01 mg/kg-d) Mink - Estimated NOAEC - (see text) <0.1 mg/kg FW diet (<0.014 mg/kg- - Auerich et al. 1985 in Eisler 1986
Mouse (range of max) (mean of max)	 0.28-0.45 0.37	Measured (Max PCB Conc, WB)	Vegetation and Prey	0.02 (calculated SS)	0.06 EPA 1993	1.0	Terr. plants 0.44 Terr. inverts 0.56 EPA 1993	9.7 0.8 TOTAL = 10.5	5.5 EPA 1993	21 EPA 1993	2.8	25-100 mg/kg FW diet (3 weeks) - (6.5-26.1 mg/kg-d) White-footed Mouse - Reduced Aestivation - Sanders and Kirkpatrick 1977 in Eisler 1986	<0.5 mg/kg-d (rat NOAEC) - Grant 1983 in Eisler 1986

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Receptor	Total PCB Conc[1] (ABSAs 3-10) (ppm)	Method	Primary Exposure Media	Mean BCF/BAF	Home Range (hectares)	Site Foraging Frequency (SFF)[2]	Dietary Fraction (DF)	Total Dietary PCB Conc (B_{prey} *H) (mg/kg FW diet)	IR (g/d)	BW (g)	APDD (mg/kg/d) $\frac{I^{*} J^{*} G}{K}$	LOAEC (exposure duration) Species -Effect - Reference	Criteria, Threshold, or NOAEC
Robin (mean)	0.93	Estimated [(mean U95 PCB Conc SS* terr Plant BAF*DF)+ (mean of max PCB Conc Earthworms* DF)]*BAF for birds	Vegetation and Prey	0.08 (geometric mean of BAFs based on brain residues in starlings, blackbirds, and cowbirds that survived after being fed 1,500 mg/kg PCB FW diet - residues measured at 50% mortality point) (Stickel et al. 1984 in Eisler 1986)	0.48 EPA 1993	1.0	Terr. Plants 0.49 Terr. Iinverts 0.51 EPA 1993	10.8 0.8 TOTAL = 11.6	92 EPA 1993	77 EPA 1993	13.9	5 mg/kg FW diet (unknown exp. duration) (6.0 mg/kg-d) -Chicken - Reproductive Impairment - Heinz et al. 1984 in Eisler 1986	<3.0 mg/kg FW diet (<3.6 mg/kg-d) - McLane and Hughes 1980 in Eisler 1986
GH Owl	Not Determined	NA	Prey	Not Determined	700 Based on mean value for red-tailed hawk, EPA 1993	1.0	Terr. inverts 0.20 Herps 0.20 Birds 0.20 Mammals 0.40 Estimated from values for red-tailed hawk, EPA 1993 Mammals = mouse	0.30 0.68 0.19 0.15 TOTAL = 1.3	113 EPA 1993	1,126 Estimated from red-tailed hawk, EPA 1993	0.13	33 mg/kg FW diet (~2 months) (3.3 mg/kg-d) American Kestral - Reduced Sperm Production - Bird et al. 1983 in Eisler 1986	<3.0 mg/kg FW diet (<0.30 mg/kg-d - McLane and Hughes 1980 in Eisler 1986

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Receptor	Total PCB Conc[1] (ABSAs 3-10) (ppm)	Method	Primary Exposure Media	Mean BCF/BAF	Home Range (hectares)	Site Foraging Frequency (SFF)[2]	Dietary Fraction (DF)	Total Dietary PCB Conc (B_{prey}*H) (mg/kg FW diet)	IR (g/d)	BW (g)	APDD (mg/kg/d) $\frac{I*J*G}{K}$	LOAEC (exposure duration) Species-Effect - Reference	Criteria, Threshold, or NOAEC
Red Fox	Not Determined	NA	Prey	Not Determined	708 EPA 1993	1.0	Terr. Plants 0.11 Terr. Inverts 0.04 Herps 0.08 Birds 0.19 Mammals 0.58 EPA 1993 Mammals = mouse + muskrat	2.4 0.06 0.27 0.18 1.4 Total = 4.4	752 EPA 1993	4,700 EPA 1993	0.70	No Available Data	<0.26 mg/kg-d dog NOAEC - Grant 1983 in Eisler 1986
Bald Eagle	Not Determined	NA	Prey	Not Determined	2,500 EPA1993	1.0	Fish 0.77 Birds 0.17 Mammals 0.06 Epa 1993 Mammals = mouse	4.9 0.16 0.02 TOTAL = 5.1	450 EPA 1993	3,750 EPA 1993	0.61	33 mg/kg diet (4.0 mg/kg-d) Reproductive effects in American Kestrel (Bird et al. in Eisler 1986)	3.0 mg/kg FW diet (0.36 mg/k -d) for protectio of birds, based o screech owl stud (McLane and Hughes 1980, ii Eisler 1986)

WB: Whole Body
BCF/BAF: Whole Body Concentration Biota / Concentration Exposure Medium
LOAEC: Lowest observed adverse effect concentration
SW: Surface Water
SED: Streambed Sediment
FP SED: Floodplain Sediment
SS: Surface Soil
FW: Fresh Weight
ACR: Acute to Chronic Ratio
* : Value based on half the analytical detection limit (< detection limit value)

1. Estimated PCB concentration for Biota = (Conc SW or SED * BCF) or (Conc SS * BAF). Whole body PCB concentration for great horned owl, red fox, and bald eagle not determined. Toxicity data associated with whole body PCB concentrations for these species unavailable.
2 SFF = Site Area 518,000 hectares / Home Range
3 Average PCB Conc of prey (PREY TYPE) items based on
   - the estimated average U95 PCB concentration for aquatic plants (AQUATIC PLANTS, 0.043))
   - the estimated average U95 PCB concentration for terrestrial plants (TERRESTRIAL PLANTS, 22)
   - the mean of maximum PCB concentration in earthworms (TERRESTRIAL INVERTEBRATES, 1.5)
   - the estimated average U95 PCB concentration in benthic macroinvertebrates (AQUATIC INVERTEBRATES, 0.69)

- the average of U95 WB PCB concentrations for carp, sucker, bass (FISH, 6.4)
- the average of (the average U95WB PCB concentration for fish, 6.4) and (the average maximum PCB concentration for mouse, 0.37) (HERPS, aquatic and terrestrial reptiles and amphibians, 3.4)
- the estimated average PCB concentration for robin (BIRDS, 0.93)
- the average maximum PCB concentration for mice (MAMMALS, except for mink and fox prey, 0.37)
- the average of (the average maximum PCB concentration for mice, 0.37) and (the average maximum PCB concentration for muskrat (4.5) (MAMMALS, 2.5)

ASSUMPTIONS:

- Earthworms are conservative and appropriate representatives for terrestrial invertebrate prey
- Consumers of fish ingest equal amounts of forage, rough, and game fish (represented by sucker, carp, smallmouth bass)
- Whole body PCB concentrations for HERPS (reptiles and amphibians) consumed as prey can be adequately estimated by averaging U95 measured values for fish (aquatic exposure) and maximum values for mice (terrestrial exposure).
  Fish represent aquatic larval amphibians, mice represent terrestrial herps (e.g., toads) and the mean of the two represent semi-aquatic reptiles and amphibians.
- Birds most representative of species consumed by predators are omnivorous passerine birds, represented by American robin
- Mammals most representative of species consumed by predators other than mink are omnivorous small terrestrial mammals, represented by white-footed/deer mice (muskrat and mice represent mammals consumed by mink)